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ABSTRACT

This manual is intended to assist heavy equipment instructors in teaching the latest concepts and functions of heavy equipment. It includes 7 sections and 27 instructional units. Sections (and units) are: orientation (shop safety and first aid, hand tools and miscellaneous tools, measuring, basic rigging and hoisting), engines (basic engine principles; engine evaluation, removal, and disassembly; cleaning, inspecting, and reconditioning gasoline and diesel engines; engine reassembly and installation), engine accessories (lubrication systems, air-intake and exhaust systems, fuel systems, cooling systems, electrical systems), hydraulics (hydraulic systems, brake systems), auxiliary systems (power trains, tracks, deck machinery, booms and other accessories), suspension (steering systems, tires, suspension systems, bearings and seals), and cutting and welding (arc welding, oxyacetylene cutting, oxyacetylene braze welding). Eight basic components form a unit: performance objectives (unit and specific objectives), suggested teacher activities, information sheets (content essential for meeting cognitive objectives written in topical outline form), assignment sheets, job sheets, transparency masters, tests, and answers to tests and assignment sheets. (YLB)

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heavy equipment mechanic

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Heavy Equipment Mechanic

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HEAVY EQUIPMENT MECHANIC

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FOREWORD

Leaders in the construction industry face an endless challenge when training workers. In an effort to promote high-quality and uniform training programs in this industry, representatives of The Associated General Contractors of America entered into an agreement with the Oklahoma State Department of Vocational and Technical Education/Curriculum and Instructional Materials Center to develop training materials. Since 1973 seven AGC/CIMC manuals have been developed, distributed, and used in local chapters.

In December of 1981, work began on another new manual. This publication was designed to help instructors and their students understand the latest concepts and functions of heavy equipment. The contents of *Heavy Equipment Mechanic* are the product of close coordination between contractors, heavy equipment mechanics, and vocational educators. Without a doubt, this manual represents a conscious effort to meld the practical experience of the construction industry with the expertise of developers of instructional materials in the vocational education field.

The purpose of this manual is to assist heavy equipment instructors in providing a high-caliber instructional program. Although the format reflects the organization of a systematic approach to instructional materials development and the latest in educational technological innovations, the information in *Heavy Equipment Mechanic* should be adapted and modified to coincide with local conditions. Furthermore, the materials should be coupled with the instructor's own methods, experience, and additional materials to make the training process complete.

Francis Tuttle, Director
Oklahoma State Department of
Vocational and Technical Education

Robert B. Fay, Chairman
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PREFACE

For many years contractors and those responsible for training mechanics have felt the need for instructional materials to be used in training the heavy equipment mechanic. In 1980, The Associated General Contractors of America, with the cooperation and support of the Oklahoma State Department of Vocational and Technical Education/Curriculum and Instructional Materials Center, accepted the challenge to produce a manual for use in training heavy equipment mechanics.

Instructional material in this manual is written in terms of student performance, using measurable behaviorable objectives. This is an innovative approach to teaching that accents and augments the teaching/learning process. Criterion-referenced evaluation instruments provide for a uniform measurement of student progress.

Instructors for equipment mechanics are faced with the challenge of providing students with the skills and related information necessary to meet the demands of a changing profession. Competition for jobs is greater than ever. Therefore, the mechanic must be better trained and better equipped to find and retain meaningful employment.

The purpose of this manual is to assist equipment mechanic instructors in providing instruction throughout the industry. This publication should be supplemented by each instructor's methods and materials. Any information in this manual that does not concur with the instructor's course of study can very easily be modified to meet personal needs.

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Laborn J. "Bud" Hendrix, Curriculum Writer
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USE OF THIS PUBLICATION

Instructional Units

Heavy Equipment Mechanics includes seven sections and twenty-seven instructional units. A standard format was established in 1970 for development of instructional materials for all Oklahoma vocational teachers. This format includes eight basic components that form a unit of instruction: performance objectives, suggested activities for the teacher, information sheets, assignment sheets, job sheets, transparency masters, tests, and answers to tests and assignment sheets. Depending on the specific objectives, there may or may not be transparency masters, assignment sheets, or job sheets included in the unit of instruction.

All of the unit components "zero in" on measurable and observable learning outcomes. Teachers are encouraged to supplement, personalize, localize, and motivate with these materials in order to develop a complete teaching/learning process.

Units of instruction are designed for use in more than one lesson or class period of instruction. Careful study of each unit of instruction by the teacher will help him or her determine the following

A. Amount of material that can be covered in each class period
B. Skills that must be demonstrated
    1. Supplies and equipment needed
    2. Amount of practice needed
    3. Amount of class time needed for demonstrations
C. Supplementary materials, such as pamphlets and filmstrips, that must be ordered
D. Resource people who must be contacted

Performance Objectives (white pages)

Each unit of instruction is based on the performance needed for successful employment in an occupational area. Performance objectives are stated in two forms: unit objectives, stating the subject matter to be covered in a unit of instruction, and specific objectives, stating the performance necessary to reach the unit objective.

Since the objectives of the unit provide direction for the teaching/learning process, it is important that teachers and students have a common understanding of the intent of the objectives. Following is a list of performance terms, their meanings, and behavioral synonyms that may have been used in this material.

A. Name — The individual supplies a name for objects, events, or people

    Behavioral synonyms: Label, list, letter, record, reiterate, repeat, write

B. Identify — The individual selects a named, described, or pictured object by pointing to it, touching it, picking it up, or selecting it

    Behavioral synonyms: Select, mark, match, choose, judge

C. State a rule — The individual communicates a relationship or principle that could be used to solve problems or perform a task

D. Apply a rule — The individual supplies an answer to a problem by using a stated relationship or principle

Behavioral synonyms: Solve, calculate

E. Describe — The individual relates sufficient characteristics or properties of an object or event so that a second individual will be able to state what is being discussed

Behavioral synonyms: Define, discuss, interpret, recite, tell how, tell what happens when

F. Distinguish — The individual selects an object or event from two or more that are easily confused

Behavioral synonyms: Discriminate, differentiate

G. Order — The individual arranges three or more objects or events in a sequence based on a stated property

Behavioral synonyms: Arrange, sequence, list in order, classify, divide, isolate, sort

H. Construct — The individual makes a physical object, a verbal statement, or a drawing

(NOTE: *Construct* is used when the finished product or result is important.)

Behavioral synonyms: Draw, make, build, design, formulate, reproduce, transcribe, convert, put together, compile

I. Demonstrate — The individual performs several operations necessary to carry out a specified process

(NOTE: *Demonstrate* is used when it is desirable to watch the student perform a task, one of the highest levels of student performance.)

Behavioral synonyms: Show your work, show procedure, perform an experiment, perform the steps, operate, remove, replace, turn off/on, (dis)assemble, (dis)connect

The objectives should be provided for students and stressed throughout the teaching/learning process. This will help answer any questions concerning performance requirements for each instructional unit. The objectives can also help determine teaching strategies and instructional methods. Prepare for each unit by deciding how each objective can best be taught.

The objective sheet may also be used as a quick pretest to determine prior knowledge of students and to determine whether further study or activities are necessary. Instructors should feel free to modify, delete, or add objectives in order to meet the needs of the students and community. When changes in objectives are made, the instructor should remember to supply the needed information, assignment and/or job sheets, and criterion test items.

Suggested Activities (pink pages)

This component is included only in instructor material. The suggested activities page assists instructors during the preparation stage of the teaching/learning process by providing suggestions for delivery and/or presentation during the instructional process. Read the suggested activities before teaching the units to allow time to obtain supplemental materials, prepare audiovisual materials, and contact outside resources. Duties of the instructor will vary according to the particular unit.

The references that are listed are ones used in the development of each unit. They should be used by the instructor to supplement her or his knowledge of the subject area or to help students with particular interests or occupational objectives in the area covered.

Information Sheet (green pages)

The information sheet provides "must know" content essential for meeting the cognitive (knowledge level) objectives of the unit. The information is written in a topical outline form and is keyed to the specific objectives.

Instructors will find that the information sheet serves as an excellent guide for presenting background knowledge necessary to develop the skills specified in the unit objective. The information sheet may also be used for coordination activities and advisory committees.

Students should read the information sheet before the information is discussed in class. Space is provided in margins for students and instructors to add notes that supplement, localize, personalize, or provide motivation for each unit.

Transparency Masters (white pages in instructor material and green in student material)

Transparency masters provide information in a special way. Transparencies direct the class's attention to the topic of discussion. Transparencies may present new information, or they may reinforce information presented in the information sheet. They are particularly effective when identification is necessary. Make transparencies and place them in the notebook where they will be immediately available for use.

Assignment Sheets (brown pages)

Assignment sheets give students a chance at problem solving, self-assessment, and/or practical experience with the information. They assist students in the application of knowledges that are necessary prerequisites to skill development. These may be given to the student for completion in class or used for homework assignments. Answer sheets are provided when appropriate and can be used by the student and/or instructor for checking student progress.

Job Sheets (blue pages)

Job sheets are another important segment of a unit of instruction. The job sheets provide a list of equipment, tools, and materials needed to complete a manipulative or psychomoter skill. They describe a step-by-step procedure needed to complete each task or job. Diagrams, photographs, and illustrations are provided to assist students in achieving the skill.

Instruments in job sheets are not in order of use. This should be taught in the classroom. In this way, students will not depend entirely on job sheets for instrument setup.

A instructor should demonstrate to students the procedures outlined in each job sheet. Furthermore, the instructor needs to localize the job sheet according to the equipment and supplies available in the local situation. Job sheets also furnish potential employers with a picture of the skills being taught and the performances they might reasonably expect from a person who has had this vocational instruction.

Tests (yellow pages)

This component provides criterion-referenced evaluation of every objective listed in the unit of instruction. It is crucial to note that both paper/pencil and performance objectives must be evaluated.

The tests may be written or oral. It is recommended that the tests be divided into shorter tests covering three or four objectives at a time and given soon after those objectives have been covered. A selection of questions from the units covered may be used for final tests at the end of each term if desired. If objectives have been added, deleted, or modified, be sure to make the changes on the test.

The acceptable response on a unit test, 85 percent in most units, may be raised or lowered to fit the topic or students' ability levels. The percentage applies to the overall score, not to each individual question. The final unit grade should be obtained by using the paper/pencil score along with evaluations of student demonstrations of the desired skills.

Answers to Test and Assignment Sheets (pink pages)

These components are designed to assist the instructor in evaluation of student performances.

Page Numbering

Each publication from the Curriculum and Instructional Materials Center is assigned a specific abbreviation. For example, *Heavy Equipment Mechanic* has been abbreviated HEM. The units are then numbered consecutively within each section. An example of a page number is IE-1-A. Since CIMC publications are loose leaf, this system of page numbering was adopted so that pages from different manuals would not get mixed up.

Methods of Disseminating Material

Material may be given out a unit or page at a time to keep the material before the student always new. Some instructors ask students to furnish a three-ring binder for the current unit of study. This is convenient for taking the material home to study. Upon completion, each unit is then placed in a larger binder. The large binders may be purchased at cost from the CIMC. Some instructors store the materials by units in filing cabinets or boxes until needed. All the units may be given out at once if desired.

For best results, provide student materials for each student. Student materials contain everything but the test answers, answers to assignment sheets, and suggested activities. All tests are collated at the back of student material and should be removed and stored until needed. Students should be allowed to take their materials home at the end of the year.

Teaching Methods

It is a challenge to keep students motivated. Supplement the objectives by providing the "why," personal experiences, and current information. Prepare for each unit by deciding how each objective can best be taught. Allow students to become involved in preparing and planning.

Competency Profiles

Competency profiles are folders used to document student performance. The profile contains a list of the specific job competencies that should be achieved prior to leaving the training program.

SHOP SAFETY AND FIRST AID
UNIT I

UNIT OBJECTIVE

After completing this unit, the student should be able to state reasons for practicing shop safety and should be able to state personal and general shop safety rules. The student will show this knowledge by completing assignment sheets, job sheets, and unit test with a minimum score of 100 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match terms associated with shop safety to their correct definitions.
2. State reasons for practicing shop safety.
3. State personal safety rules.
4. State rules for general shop safety.
5. Match colors of the safety color code to their correct applications.
6. Select from a list the components of the fire triangle.
7. Match classes of fires to their correct descriptions.
8. Match types of fire extinguishers to the classes of fires for which each is used.
9. State safety rules concerning flammable liquids.
10. Describe sources and effects of common breathing hazards.
11. Describe procedures used to maintain a clean and orderly work area.
12. Arrange in order correct procedures for lifting a heavy object.
13. Name reasons why knowledge of first aid is important.
14. Discuss reasons why first-aid skills are needed.
15. Arrange in order immediate steps to follow when giving first aid to an accident victim.
16. Select from a list factors to consider in first-aid treatment of shock.
17. Classify types of burns by degree according to description.

OBJECTIVE SHEET

18. Match first- , second- , and third-degree burns to their correct first-aid treatments.

19. Describe steps to follow to control bleeding by direct pressure.

20. Arrange in order steps to follow for mouth-to-mouth resuscitation.

21. Complete a safety-pledge form.

22. Analyze accident case studies.

23. Evaluate situations involving hazards.

24. Demonstrate the ability to

    a. Lift a heavy object properly.

    b. Give mouth-to-mouth resuscitation.

SHOP SAFETY AND FIRST AID
UNIT I

SUGGESTED ACTIVITIES

I. Suggested activities

A. Order films to supplement unit.

1. *Housekeeping Means Safekeeping.* Color, 10 minutes, Journal Films, Inc., 1975. Available from Journal Films, Inc., 930 Pitner Avenue, Evanston, Illinois 60202.

2. *Stop a Fire Before It Starts.* Color, 10 minutes, Journal Films, Inc., 1975. Available from Journal Films, Inc., 930 Pitner Avenue, Evanston, Illinois 60202.

3. *A New Way to Lift.* Color, 9 minutes, Journal Films, Inc., 1970. Available from Journal Films, Inc., 930 Pitner Avenue, Evanston, Illinois 60202.

4. *The Industrial Weight Lifter.* Color, 12 minutes, Ruddel Films for Industrial Accident Prevention Association Ontario and Canada Packers Ltd., 1965. Available from International Film Bureau Inc., 332 South Michigan Avenue, Chicago, Illinois 60604.

B. Obtain transparencies.

(NOTE: Transparencies are available from AGC and CIMC.)

C. Provide students with information, assignment, and job sheets.

D. Discuss unit and specific objectives.

E. Provide students with information, assignment, and job sheets.

F. Discuss information and assignment sheets.

G. Demonstrate and discuss procedures outlined in job sheets.

H. Contact a safety engineer as a resource person for class concerning safety on the job.

I. Contact insurance company representative to give safety lecture.

J. Have students complete a first-aid course and become certified according to OSHA regulations.

SUGGESTED ACTIVITIES

K. Have students demonstrate the ability to practice safety and first aid in accordance with MSHA and OSHA safety standards.

L. Give test.

M. Complete appropriate section of competency profiles.

(NOTE: Competency profiles are available from AGC and CIMC.)

II. Instructional materials

A. Objective sheet

B. Suggested activities

C. Information sheet

D. Transparency masters

1. TM #1 — Components of the Fire Triangle
2. TM #2 — Types of Fire Extinguishers
3. TM #3 — Types of Fire Extinguishers (Continued)
4. TM #4 — Correct Procedures for Lifting a Heavy Object

E. Assignment sheets

1. Assignment Sheet #1 — Complete a Safety-Pledge Form
2. Assignment Sheet #2 — Analyze Accident Case Studies
3. Assignment Sheet #3 — Evaluate Situations Involving Hazards
4. Assignment Sheet #4 — Match Safety Colors to Their Correct Applications

F. Answers to assignment sheets

G. Job sheets

1. Job Sheet #1 — Lift a Heavy Object Properly
2. Job Sheet #2 — Give Mouth-to-Mouth Resuscitation

H. Test

I. Answers to test

SUGGESTED ACTIVITIES

III. Unit references

A. Hendrix, Laborn J. "Bud." *Heavy Equipment Operator: Basic Core.* Stillwater, Oklahoma: State Department of Vocational and Technical Education/ Curriculum and Instructional Materials Center and The Associated General Contractors of America, 1981.

B. *Shop Safety Skills.* Athens, Georgia: American Association for Vocational Instructional Materials, 1979.

SHOP SAFETY AND FIRST AID
UNIT I

INFORMATION SHEET

I. Terms and definitions

A. Accident — Any suddenly occurring, unintentional event that causes personal injury or property damage

B. Carbon monoxide — Colorless, odorless, very toxic gas contained in exhaust gas

C. Combustible — Capable of bursting into flames

D. Concussion — Stunning, damaging, or shattering effect from a hard blow; possible injury to the brain

E. Explosive — Substance tending to explode

F. Extinguish — To cause to cease burning

G. First aid — Immediate, temporary care given the victim of an accident or sudden illness until the services of a physician can be obtained

H. Flammable — Capable of being easily ignited and burning with extreme rapidity

(NOTE: *Inflammable* also means capable of being easily ignited. The term is not being used today but may still be found on older products.)

I. Hazard — Source of danger; condition that can cause an accident

J. Lockout — Locking device used on equipment for securing parts and accessories in order to maintain safety while performing service, maintenance, or repairs

K. MSHA — Mine Safety and Health Administration; established by Department of Labor; organization that sees that mine operators promote safe and healthful working conditions and abide by mine safety and health regulations

L. OSHA — Occupational Safety and Health Act; federal legislation designed to ensure safe and sanitary working conditions for employees

M. Pneumatic — Air-powered

N. Pressurized — Stored under pressure greater than the pressure of the atmosphere

INFORMATION SHEET

O. Radiation — Combined processes of emission, transmission, and absorption of radiant energy

P. Resuscitation — Act of bringing a person back to full consciousness

Q. Safety — State or condition of being safe; freedom from danger, risk, or injury

R. Solvent — Liquid substance capable of dissolving or dispersing one or more other substances

II. Reasons for practicing shop safety

A. Prevent physical harm to yourself and others

B. Prevent loss or damage of equipment or materials

C. Avoid loss of work

D. Avoid possible loss of pay

E. Lower cost to employer

F. Lower insurance rates

G. Prevent loss of job

H. Prevent hardship on family

I. Provide regular job schedules

J. Keep insurance costs down

K. Affect attitude and morale

L. Increase productivity

III. Personal safety rules (Assignment Sheets #1 and #2)

A. Wear clothing that is appropriate to the job being performed

B. Wear safety glasses and other safety equipment where required

C. Be alert, and conduct yourself in a manner to ensure safe practices

D. Do not jump onto or off equipment

E. Remove ties, loose sleeves, and other loose clothing when working around machine tools or rotating equipment

INFORMATION SHEET

F. Remove rings and other jewelry when working

G. Use soap and water frequently to prevent skin disease

H. Confine long hair before working around running equipment

I. Be familiar with location of first-aid equipment

J. Be familiar with location and type of available fire extinguishers

IV. Rules for general shop safety (Assignment Sheet #2)

A. Keep work area clean

B. Store flammable materials in metal containers with self-sealing lids

C. Keep all tools sharp, clean, and in good working order

D. Retain guards, tool rests, and safety devices on all equipment

E. Never leave an operating machine unattended

F. Disconnect power lock and tag out machine tools before performing maintenance

G. Use correct, properly fitting wrenches on nuts and bolts

H. Clean up spilled liquids immediately

I. Do not use compressed air to clean yourself or your clothing

J. Be conscious of others' safety

K. Be sure that others are at a safe distance when you are operating equipment

L. Do not lean against machines while operating them

M. Avoid startling or distracting others who are operating equipment

N. Report defective tools and equipment to your supervisor

O. Report all accidents to your supervisor, regardless of nature or severity

P. Maintain safety rules and limitations on all equipment according to specifications and manufacturer's regulations

Q. Develop a positive attitude toward safety; do not become overconfident; stay alert

INFORMATION SHEET

R. Keep all tools and equipment properly stored when not in use

S. Use proper grounds on all electrical equipment

T. Use jack stands when working under equipment

U. Use solvents and cleaning fluids only after determining what their properties are, what kind of work they do, and how they should be used

V. Never operate equipment until you have been properly checked out on its operation and safety regulations

W. Use caution when operating mobile equipment, including hoists, cranes, and winches

X. Never weld or cut galvanized metal without good ventilation

Y. Never operate engines in unventilated shops

Z. Be sure to use lockouts and safety levers as prescribed by OSHA regulations while performing maintenance and repairs

V. Colors and applications of the safety color code (Assignment Sheet #4)

A. Safety red

1. Designates danger and emergency

2. Identifies fire-fighting equipment

3. Identifies portable containers for flammable liquids

4. Identifies emergency-stop bars, buttons, and switches on machinery

B. Safety orange

1. Designates dangerous machine parts that may cut, crush, shock, or otherwise injure

2. Designates hazards such as pulleys, gears, rollers, cutting devices, and power jaws when enclosure doors or guards are open

3. Designates safety starter buttons, inside covers of shields, switch boxes, and parts of equipment that may cause electrical shock

C. Safety yellow

1. Designates caution

INFORMATION SHEET

2. Designates flammable liquids with flash point of 80°F or lower

3. Designates safety cans, other containers of flammable liquids, and waste containers for explosive and/or combustible materials

4. Outlines work areas and traffic lanes

5. Marks obstacles such as low beams, protruding extensions, and steps

D. Safety blue

1. Designates information and caution against machines or equipment out of order or under repair

2. Designates information and caution on outside of large switch boxes and control covers

3. Designates out-of-order signs on equipment

E. Safety green

1. Designates location of first-aid equipment

2. Designates location of safety equipment

(NOTE: This application applies to safety equipment other than fire-fighting equipment.)

F. Safety black and white (used individually or in combination)

1. Designates traffic flow

2. Designates barricades

3. Designates storage areas

4. Designates housekeeping purposes

G. Safety purple, or black symbol on safety yellow, or magenta on safety yellow — Designates radiation hazard

H. Safety ivory

1. Improves visibility

2. Reflects light and shows the way

3. Designates tooling-action areas of machines and edges of tables and workbenches

INFORMATION SHEET

I. Yellow bands — Indicate natural-gas and steam pipes

J. Blue bands — Indicate compressed-air pipes

K. Black bands — Indicate vent-line pipes

L. Grey bands — Indicate water pipes

VI. Components of the fire triangle (Transparency #1)

(NOTE: To produce fire, the following three elements are necessary and must be present at the same time. If any one of the three is missing, a fire cannot be started. With the removal of any one of the three, the fire will be extinguished.)

A. Fuel

EXAMPLE: Any flammable material

B. Heat

(NOTE: Enough heat has to be present to raise the fuel to its ignition temperature.)

C. Oxygen

(NOTE: Oxygen is necessary to sustain combustion.)

VII. Classes of fires

A. Class A — Fires that occur in ordinary combustible materials such as wood, paper, rags, and rubbish

B. Class B — Fires that occur with flammable liquids such as gasoline, oil, grease, paint, thinners, and solvents

C. Class C — Fires that occur in or near electrical equipment such as motors, switches, circuit breakers, and electrical wiring

(CAUTION: Never use pressurized water on class C fires.)

D. Class D — Fires that are caused by or occur with combustible metals such as iron or magnesium

(CAUTION: Get away from magnesium fires immediately.)

INFORMATION SHEET

VIII. Types of fire extinguishers and the classes of fires for which each is used (Transparencies #2 and #3)

A. Pressurized water — Used on class A fires *only*

B. Carbon dioxide (CO_2) — Used on class B and C fires

C. Multipurpose dry chemical — Used on class A, B, and C fires

D. Dry powder — Used on class D fires

E. Water pump tank — Used on class A fires *only*

F. Foam — Used on class B fires *only*

IX. Safety rules concerning flammable liquids

A. Know the location and type of fire extinguishers to use for flammable liquids

B. Store all flammable liquids in approved safety containers

C. Use only approved cleaning solvents to clean parts

(CAUTION: Never use gasoline or diesel fuels.)

D. Do not fuel a running or hot gasoline engine

E. Do not operate an engine that has a gasoline leak

F. Change oil- or gasoline-soaked clothing immediately

G. Wipe up spilled oil, cleaning solvents, and gasoline immediately, and dispose of rags in the proper containers

H. Store flammable liquids only in prescribed locations

I. Clearly mark all flammable liquids and storage areas

INFORMATION SHEET

X. Sources and effects of common breathing hazards (Table 1)

(NOTE: Other breathing hazards may be found in OSHA regulations.)

TABLE 1

Hazards	Sources	Effects
Carbon monoxide	Engines	Displaces oxygen in the blood; causes dizziness, drowsiness, headaches, and sudden death
Nitrogen oxide and iron oxide	Welding	Causes accumulation of fluid in the lungs
Trichloroethylene, petroleum solvents, carbon tetrachloride	Parts cleaning	Causes headaches and lung, kidney, and liver damage
Metallic substances, toxic vapors, carbon disulfide, naphtha, benzene	Paint and glue products	Has narcotic effect; long-term exposure may cause damage to lungs, liver, kidneys, and bone marrow
Asbestos fibers	Construction, insulation, brake work	Causes lung cancer

XI. Procedures used to maintain a clean and orderly work area (Assignment Sheet #3)

A. Arrange machinery and equipment to permit safe, efficient work practices and ease in cleaning

B. Stock materials and supplies in proper places

C. Store tools and accessories in proper places

D. Keep work area clean and clear of hazards

E. Dispose of combustible materials properly

EXAMPLE: Store oily rags in self-closing or spring-lid metal containers.

F. Keep cleaning supplies and housekeeping equipment in a central location

XII. Correct procedures for lifting a heavy object (Transparency #4; Assignment Sheets #2 and #3)

(NOTE: Know your physical capabilities and limits; do not attempt to lift an object that is too heavy.)

A. Step up to object with feet apart; place one foot beside object and one behind

(NOTE: Lift with legs and not with the back.)

INFORMATION SHEET

B. Keep back straight, nearly vertical

C. Tuck chin in

D. Grasp object with whole hand

E. Tuck in elbows and arms

F. Hold load close to body

G. Keep body weight directly over feet

H. Lift object

XIII. Reasons why knowledge of first aid is important

A. May mean the difference between life and death

B. May mean the difference between temporary or permanent injuries

C. Trains one in what to do and what not to do in an emergency

XIV. Reasons why first-aid skills are needed

A. Accidents are the number-one cause of death

B. There may not be time to wait for professional medical help after an accident

C. Safety awareness needs to be promoted at work

XV. Immediate steps to follow when giving first aid to an accident victim

(NOTE: These steps are important not only because they may help the victim, but also because the information learned must be reported accurately when you call for professional medical help.)

A. Observe overall emergency

(NOTE: Find out exactly what happened as quickly as possible because this will prepare you for examining the victim and determining what to do first.)

INFORMATION SHEET

B. Check breathing

(NOTE: Check breathing by laying your hand on victim's chest and holding your ear to victim's nose and mouth.)

C. Check pulse or heartbeat

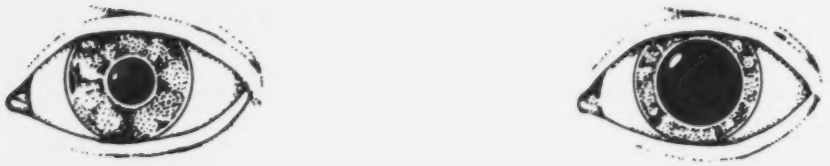
(NOTE: Pulse in wrist may be reduced, so check pulse in neck or groin.)

D. Observe pupil reaction of the eyes

(NOTE: Pupils may be constricted or dilated. See Figure 1.)

EXAMPLE:

FIGURE 1



Constricted Dilated

E. If victim is conscious, check alertness level by asking questions about physical status

F. Begin definite first-aid treatment for symptoms

(NOTE: If you are not sure of symptoms and/or cause of emergency, do not move the victim. Keep victim quiet and warm; do not give victim anything to drink or eat.)

XVI. Factors to consider in first-aid treatment of shock

(NOTE: Shock may be caused by the loss of any body fluids resulting from prolonged conditions, severe injuries, infection, heart attack or stroke, poisoning from different sources, and the lack of oxygen. Shock may also be caused by metabolic disorders such as diabetes.)

A. Keep victim lying down

B. Maintain adequate supply of oxygen

C. Cover victim to prevent loss of body heat and to stabilize blood circulation

INFORMATION SHEET

D. Use good judgment in giving liquids; consider the victim's condition and the cause of shock

(NOTE: Give only a few sips of liquid at a time; give no alcoholic beverages. If victim is in danger of choking or vomiting, do not give any liquids.)

E. Get medical help as soon as possible

XVII. Types of burns and their descriptions

A. First degree

(NOTE: First-degree burns can be caused by sunburn, light contact with hot objects [accidentally touching a hot manifold or other engine component], or contact with hot water or scalding steam [radiator].)

1. Redness or discoloration
2. Mild swelling or pain
3. Rapid healing

B. Second degree

(NOTE: Second-degree burns can be caused by contact with hot liquids [boiling radiator water, hot tar or asphalt, battery acid] or a deep sunburn.)

1. Pain greater than first degree
2. Damage extending into first layer of tissue
3. Mottled or red areas
4. Blistering
5. Considerable swelling
6. Wet appearance of burned area due to loss of plasma

C. Third degree

(NOTE: Third-degree burns can be caused by contact with flame; contact with hot objects, acid, or electricity; or immersion in hot water.)

1. Deep tissue destruction
2. Less pain due to nerve destruction

   (NOTE: Pain may be greatly diminished because nervous tissue has been burned.)

3. Charred or white appearance

INFORMATION SHEET

XVIII. First-aid treatment of first- , second- , and third-degree burns

(NOTE: When assessing burns to determine treatment, look at the percentage of the body burned and the areas injured.)

A. First degree — Apply cold water or submerge burned area in cold water; apply a dry dressing if necessary

B. Second degree — Submerge the burned area in cold water (not ice water) until pain eases; blot dry gently and apply dry, sterile dressings; do not break blisters; do not use any ointments, sprays, or home remedies on burned area

C. Third degree — Cover burns with thick sterile dressings; do not immerse in water; do not remove any tissue or burned clothing; transport victim to hospital as quickly as possible

XIX. Steps to follow to control bleeding by direct pressure

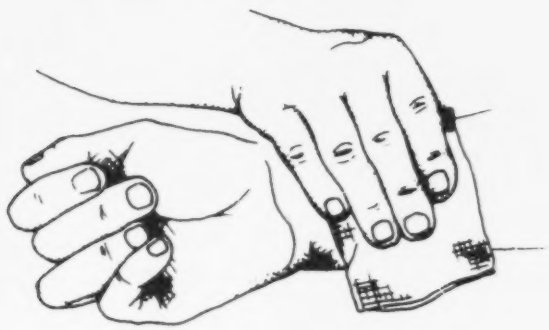
(NOTE: A victim may suffer shock and loss of consciousness from loss of blood. Because it is possible to bleed to death in a very short period of time, bleeding should be brought under control as soon as possible.)

A. Apply dressing (prepared gauze, clean handkerchief, clean articles of clothing) to area, using firm pressure with hand (Figure 2)

(NOTE: In some cases the bare hand has to be used until a suitable dressing or compress can be found.)

EXAMPLE:

FIGURE 2



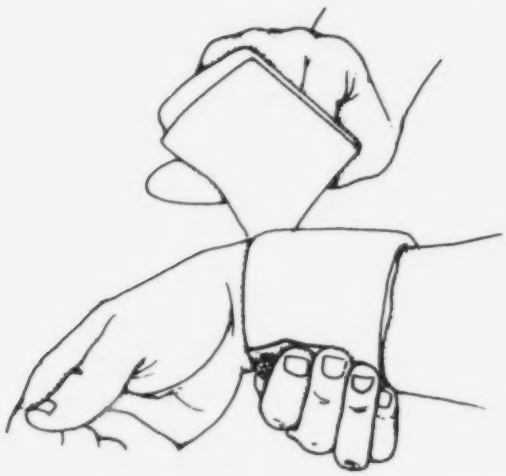
INFORMATION SHEET

B. Check frequently to see whether bleeding has stopped or slowed

(CAUTION: Do not disturb clots after they have formed. If blood soaks through cloth, do not remove; add more layers of dressing. See Figure 3.)

EXAMPLE:

FIGURE 3

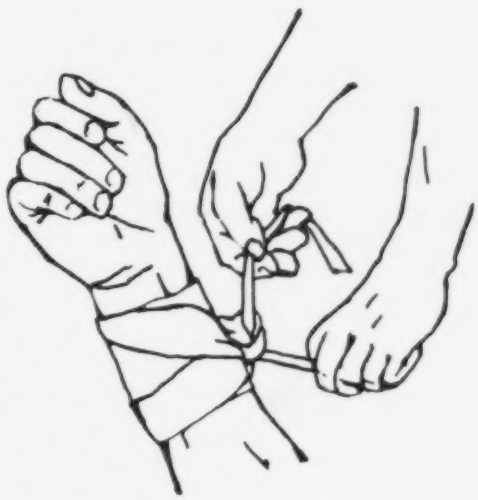


C. If bleeding is still active, apply a pressure bandage by holding the dressing in place with one hand, wrapping bandage directly over and around the injured area, and tying the knot over the wounded area (Figure 4)

(NOTE: Use firm motion, but do not wrap too tightly or circulation will be impaired.)

EXAMPLE:

FIGURE 4



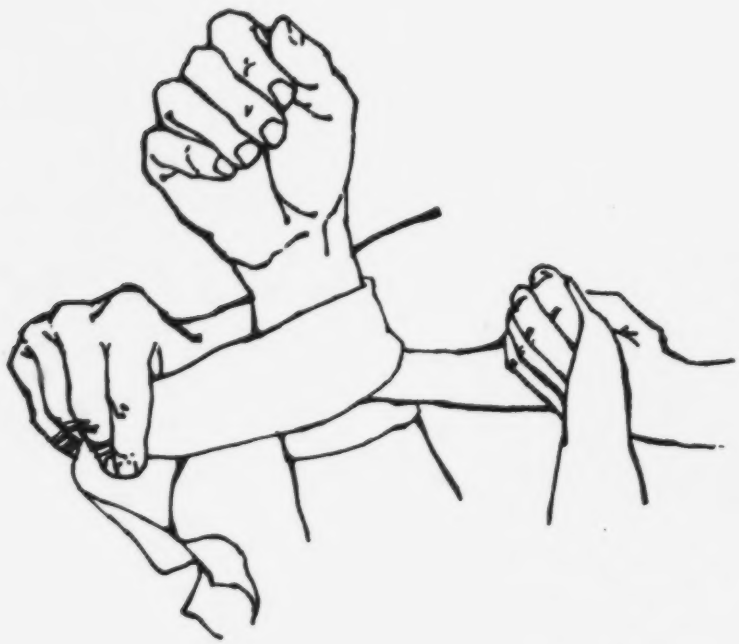
INFORMATION SHEET

D. If injured area is a limb, elevate the limb, if possible, above the level of the victim's heart (Figure 5)

(NOTE: Elevate the limb only if no apparent fracture has occurred in that limb.)

EXAMPLE:

FIGURE 5



INFORMATION SHEET

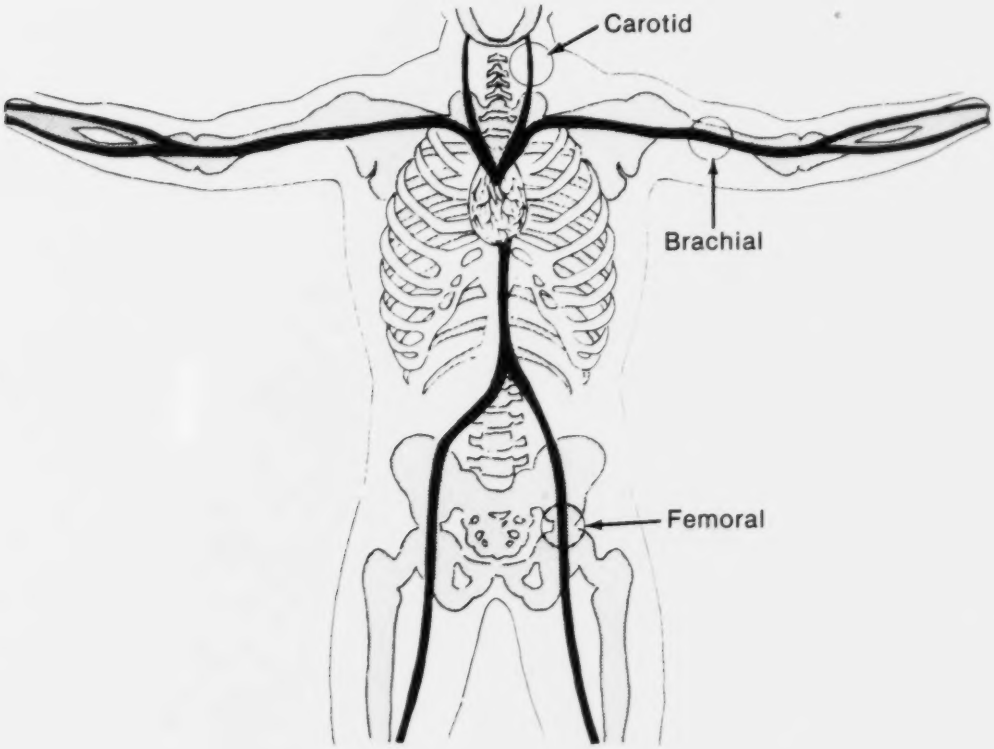
E. If bleeding continues, apply pressure on the main artery that supplies blood to the injured area

(CAUTION: Apply a tourniquet ONLY AS A LAST RESORT. Apply a tourniquet to save the victim's life, but remember that a tourniquet cuts off circulation and may cost the victim his or her limb. If you must use a tourniquet, MAKE SURE that the victim is seen by a physician as soon as possible.)

(NOTE: Refer to Figure 6 for pressure points to control bleeding in various areas.)

EXAMPLE:

FIGURE 6



INFORMATION SHEET

XX. Steps to follow for mouth-to-mouth resuscitation

A. Clear victim's air passage

B. Extend victim's chin by lifting up under neck

C. Pinch victim's nostrils shut

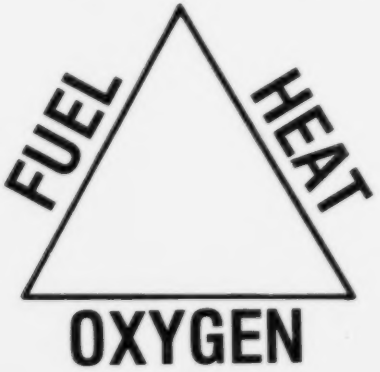
D. Inhale deeply; breathe into victim's mouth

E. Remove your mouth from victim's mouth; listen for return flow of air

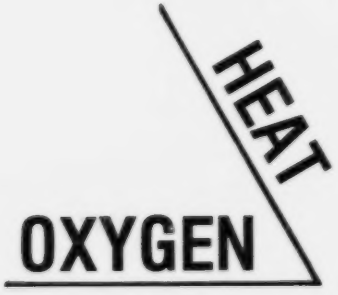
(NOTE: Continue this procedure until the victim is revived or until it is no longer necessary.)

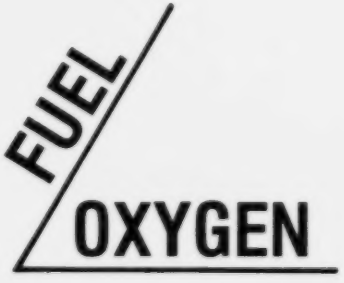
Components of the Fire Triangle

To produce fire, three things must be present at the same time.



If any one of the three is missing, a fire cannot be started. With the removal of any one, the fire will be extinguished.





Types of Fire Extinguishers

KIND OF FIRE		APPROVED TYPE OF EXTINGUISHER					
DECIDE THE CLASS OF FIRE YOU ARE FIGHTING...	...THEN CHECK THE COLUMNS TO THE RIGHT OF THAT CLASS	MATCH PROPER EXTINGUISHER WITH CLASS OF FIRE SHOWN AT LEFT Important! Using the wrong type extinguisher for the class of fire may be dangerous.					
		Pressurized Water	**Carbon Dioxide (CO_2)**	**Multipurpose Dry Chemical**	**Dry Powder**	**Water Pump Tank**	**Foam**
*Green **A** **CLASS A FIRES** **Use These Extinguishers** ORDINARY COMBUSTIBLES • Wood • Paper • Cloth, Etc.							
*Red **B** **CLASS B FIRES** **Use These Extinguishers** FLAMMABLE LIQUIDS, GREASE • Gasoline • Paints • Oils, Etc.							

*Extinguisher labels are coded (by letter, shape, and color) to help you match the correct extinguisher to the type of fire you are fighting.

A B C D

Types of Fire Extinguishers
(Continued)

KIND OF FIRE		APPROVED TYPE OF EXTINGUISHER					
DECIDE THE CLASS OF FIRE YOU ARE FIGHTING...	...THEN CHECK THE COLUMNS TO THE RIGHT OF THAT CLASS	MATCH PROPER EXTINGUISHER WITH CLASS OF FIRE SHOWN AT LEFT Important! Using the wrong type extinguisher for the class of fire may be dangerous.					
		Pressurized Water	**Carbon Dioxide (CO_2)**	**Multipurpose Dry Chemical**	**Dry Powder**	**Water Pump Tank**	**Foam**
*Blue (C) **CLASS C FIRES** **Use These Extinguishers** ELECTRICAL EQUIPMENT • Motors • Switches, Etc.							
*Yellow (D) **CLASS D FIRES** **Use This Extinguisher** COMBUSTIBLE METALS • Iron • Magnesium							

*Extinguisher labels are coded (by letter, shape, and color) to help you match the correct extinguisher to the type of fire you are fighting.

A B C ☆

Correct Procedure for Lifting a Heavy Object

SHOP SAFETY AND FIRST AID
UNIT I

ASSIGNMENT SHEET #1 — COMPLETE A SAFETY-PLEDGE FORM

NAME _____ SCORE _____

It is understood that each student and/or employee will be given proper instruction in the use of the equipment and in the correct safety procedures concerning the equipment before she or he will be allowed to operate it. The student and/or employee must assume responsibility for following safe practices. We, therefore, ask that the student and/or employee subscribe to the following safety pledge.

A. I will follow the safety rules.

B. I will never use a machine without first having permission from my instructor or supervisor.

C. I will not ask permission to use a particular machine unless I have been instructed in its use and have scored 100 percent on the safety test for that machine.

D. I will report immediately any accident or injury, no matter how minor, to my instructor or supervisor.

Date _____

Student's and/or employee's signature _____

Date _____

Foreman's signature _____

Date _____

Supervisor's or instructor's signature _____

Parental consent is necessary if the student and/or employee is under 18.

Date _____

Parent's or guardian's signature _____

SHOP SAFETY AND FIRST AID
UNIT I

ASSIGNMENT SHEET #2 — ANALYZE ACCIDENT CASE STUDIES

NAME _____ SCORE _____

Safety is a personal responsibility. Without a doubt, most accidents result from people taking careless risks. Not only can accidents cause physical harm and loss of work time, but unsafe situations and actions affect your co-workers and company.

Study each of the case studies that follow. Think through each carefully by asking yourself the following questions. What caused the accident? Could it have been avoided? What *costs* were involved besides financial ones? Then answer the questions included in each case study.

ASSIGNMENT SHEET #2

Case Study #1

Victim: Simber Lee Quentin, age thirty-six, fifteen years' experience

Job description: Moving a compressor with an oil leak from the shop to a nearby storage shed

Accident description: Simber Lee had just returned from a noon dental appointment when her supervisor asked her to move a compressor with an oil leak from the shop to a nearby storage shed. It was raining, but Simber Lee went outside to get a dolly to move the compressor. On returning, she stepped up to the machine, slipped on the oily floor, and fell. Her head struck the concrete floor, and she was knocked unconscious.

A. Assuming that you have witnessed the accident and are nearby to help, what would you do first?_____

_____

_____

B. What safety precautions did the worker observe?_____

_____

_____

C. What safety precautions did the worker fail to observe?_____

_____

_____

D. What factors may have caused the accident?_____

_____

_____

E. Could this accident have been avoided?_____ How?_____

_____

_____

F. What do you think will be some of the consequences or results of this accident?____

_____

_____

_____

ASSIGNMENT SHEET #2

Case Study #2

Victim: Carlos Jones, age forty-two, sixteen years' experience

Job description: Remove bucket from a backhoe and install a new one

Accident description: Because of his 16 years' experience, Carlos was assigned a young trainee, Peggy Braunstidt. Proud that he had been chosen by his supervisor to instruct the attractive trainee, Carlos demonstrated the proper way to lift heavy objects. But, he attempted to lift the old bucket by himself. As he attempted to lift the bucket, he heard and felt his back pop and found that he could not straighten up without severe pain.

A. Assuming that you have witnessed the accident and are nearby to help, what would you do first?_____

_____

_____

B. What safety precautions did the worker observe?_____

_____

_____

C. What safety precautions did the worker fail to observe?_____

_____

_____

D. What factors may have caused the accident?_____

_____

_____

E. Could this accident have been avoided?_____ How?_____

_____

_____

F. What do you think will be some of the consequences or results of this accident?____

_____

_____

_____

ASSIGNMENT SHEET #2

Case Study #3

Victim: Asila Niethak, age twenty-two, eleven months' experience

Job description: Repair a wheel loader and test drive it

Accident description: Proud to be given the responsibility of test driving the loader, Asila tipped her hard hat at passing motorists and recklessly increased the loader's speed. Her loader suddenly *duck walked* off the road and went down a 12-foot embankment. The loader rolled over, crushing Asila, who died instantly.

A. Assuming that you have witnessed the accident and are nearby to help, what would you do first?_____

_____

_____

B. What safety precautions did the worker observe?_____

_____

_____

C. What safety precautions did the worker fail to observe?_____

_____

_____

D. What factors may have caused the accident?_____

_____

_____

E. Could this accident have been avoided?_____ How?_____

_____

_____

F. What do you think will be some of the consequences or results of this accident?____

_____

_____

_____

ASSIGNMENT SHEET #2

Case Study #4

Victim: Carl Adams, age twenty-nine, four years' experience

Job description: Sharpen a chisel on a bench grinder

Accident description: Carl stepped up to the grinder, pushed the tool rest aside, and immediately placed the chisel on the grinding wheel and began grinding. Ginny Vogel walked up behind Carl and grabbed his arm. Startled, Carl jammed the chisel into the grinding wheel, and, as a result, metal chips flew off and into his eye. Carl immediately dropped the chisel and started rubbing his eye.

A. Assuming that you have witnessed the accident and are nearby to help, what would you do first?_____

_____

_____

B. What safety precautions did the worker observe?_____

_____

_____

C. What safety precautions did the worker fail to observe?_____

_____

_____

D. What factors may have caused the accident?_____

_____

_____

E. Could this accident have been avoided?_____ How?_____

_____

_____

F. What do you think will be some of the consequences or results of this accident?____

_____

_____

_____

SHOP SAFETY AND FIRST AID
UNIT I

ASSIGNMENT SHEET #3 — EVALUATE SITUATIONS INVOLVING HAZARDS

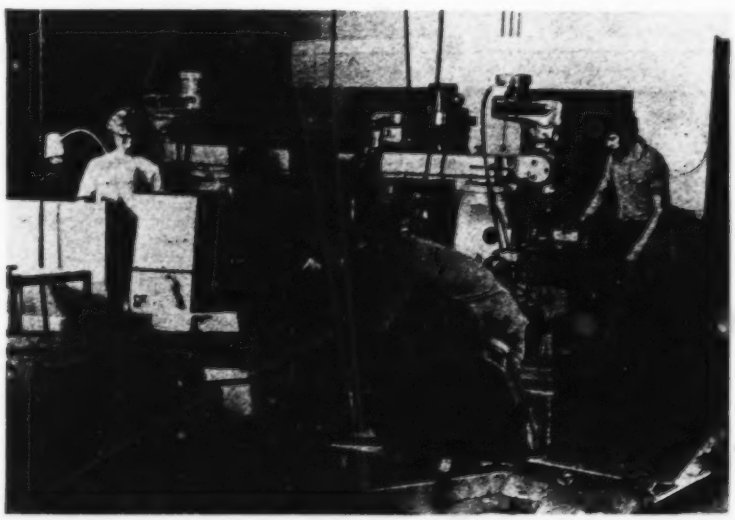
NAME _____ SCORE _____

Machines are slaves designed to do your bidding, but they are only as safe as the people using them. Machines don't think, but *you* must think if the job you are performing is to be accident-free.

Study each of the following photographs, and state which safety rules are not being observed. Indicate the corrective measures that should be taken.

(NOTE: Some photographs may depict more than one safety violation.)

A.



1. _____
2. _____
3. _____
4. _____

ASSIGNMENT SHEET #3

B.

1. _____
2. _____
3. _____
4. _____
5. _____
6. _____

ASSIGNMENT SHEET #3

C.

1. _____
2. _____
3. _____
4. _____
5. _____

SHOP SAFETY AND FIRST AID
UNIT I

ASSIGNMENT SHEET #4 — MATCH SAFETY COLORS
TO THEIR CORRECT APPLICATIONS

NAME _____ SCORE _____

Color coding is a visual way of showing safety. Think of the different colors as road signs alerting you to different safety hazards.

Match the following safety colors to their uses. Write the correct numbers in the blanks. Some colors will be used more than once.

_____A.	Designates location of first-aid equipment	1. Safety red
_____B.	Designates a hazardous area on equipment, such as the inside of an electrical fuse box	2. Safety yellow
_____C.	Designates location of fire-fighting equipment	3. Safety orange
_____D.	Designates a hazardous area such as a step-off or low-hanging pipe	4. Safety green
_____E.	Designates that a machine is out of order or under repair	5. Safety blue
_____F.	Indicates the way out of the building such as a marked aisle	6. Safety ivory
_____G.	Designates location of stop switch on a machine	7. Safety black and white (used individually or in combination)
_____H.	Designates work areas and traffic lanes	8. Safety purple
_____I.	Indicate vent-line pipes	9. Yellow bands
_____J.	Designates radiation hazard	10. Blue bands
_____K.	Designates traffic flow	11. Black bands
_____L.	Indicate natural-gas and steam pipes	12. Grey bands
_____M.	Designates edges of work tables and workbenches	
_____N.	Indicate water pipes	
_____O.	Designates location of safety equipment	
_____P.	Designates caution	
_____Q.	Designates barricades	
_____R.	Indicate compressed-air pipes	

SHOP SAFETY AND FIRST AID
UNIT I

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1 — Evaluated to the satisfaction of the instructor

Assignment Sheet #2

Student responses will vary, but the answers should include the following

Case Study #1

A. Observe overall emergency (Simber Lee may have suffered a concussion or head wound)

B. Simber Lee planned to use a dolly to move a heavy object

C. Simber Lee neglected to wipe up a spill in the work area

D. The combination of wet shoes and oil on the floor probably caused the accident

E. Yes. Simber Lee could have avoided the accident by wiping up the oil on the work-area floor

F. Accident results include personal injury and loss of work time

Case Study #2

A. Send Peggy to use site's emergency phone and telephone number to report the accident and to call for professional medical help

B. Carlos assumed the proper position for lifting heavy objects

C. Carlos tried to lift a very heavy object by himself

D. The accident was caused by Carlos' sense of pride and his carelessness regarding safe lifting measures

E. Yes. The victim should have asked for assistance in lifting the old bucket

F. Accident results include personal injury and loss of work time

Case Study #3

A. Turn off machine if possible; observe overall emergency (call to victim; check breathing and pulse or heartbeat). Telephone for professional medical help, or flag someone down and send him or her for help

ANSWERS TO ASSIGNMENT SHEETS

B. Asila wore her hard hat

C. Asila failed to drive at the low speed recommended for road testing. Asila's supervisor, however, bears most of the responsibility for this accident. The operator was too inexperienced to be test driving a loader on the road

D. The accident was caused by carelessness on the part of Asila's supervisor and by Asila's recklessness

E. Yes. Asila should have driven the loader slower and not so recklessly. The supervisor should have chosen someone more experienced for the job

F. Accident results include death, destruction of equipment and property, loss of a worker, and delay in work schedule

Case Study #4

A. Turn off machine; have victim remove his hand from his eye and observe emergency. Send Ginny to notify supervisor. Place a clean cloth or bandage over eye, and transport victim to nearest emergency medical facility

B. None

C. Carl failed to put on eye protection; he moved the tool rest aside. Ginny, however, bears part of the responsibility for this accident. If she had not startled Carl, he may not have jammed the chisel into the grinding wheel and caused the chips to fly into his eye

D. Ginny's carelessness in grabbing Carl instead of gently approaching him and Carl's carelessness in not observing the safety rules caused the accident

E. Yes. Carl should have worn proper eye protection and left the tool rest in place. Ginny should not have startled someone who was operating equipment

F. Accident results include possibility of losing an eye, loss of work time, damage to equipment, and delay in work schedule

Assignment Sheet #3

A.
1. One person not wearing eye protection
2. One person wearing long sleeves and reaching into machine
3. Guard off one machine
4. Broom and trash on floor

ANSWERS TO ASSIGNMENT SHEETS

B.
1. Broom and trash on floor
2. Guard off machine
3. Student has bar across shoulder; could hit someone or hit equipment
4. One student not wearing safety glasses
5. Student operating machine has shirttail out and long sleeves unbuttoned
6. Rags are left on machine too close to work

C.
1. Student incorrectly lifting heavy object
2. No guard on grinder and student not wearing eye protection
3. Hair not tied back on person operating grinding machine
4. Trash on floor and on workbench
5. Student leaning on machine and possibly distracting operator

Assignment Sheet #4

A.	4	G.	1	M.	6
B.	3	H.	2	N.	12
C.	1	I.	11	O.	4
D.	2	J.	8	P.	2
E.	5	K.	7	Q.	7
F.	6	L.	9	R.	10

SHOP SAFETY AND FIRST AID
UNIT I

JOB SHEET #1 — LIFT A HEAVY OBJECT PROPERLY

(NOTE: It is understood that each student will be given instructions on proper lifting techniques before attempting to lift a heavy object. It is also advised that students view the film *A New Way to Lift.*)

I. Material and equipment

A. A person

B. Heavy object

II. Procedure

(NOTE: Know your physical capabilities and limits; do not attempt to lift an object that is too heavy.)

A. Step up to object with feet apart; place one foot beside object and one behind (Figure 7)

FIGURE 7

JOB SHEET #1

B. Keep back straight, nearly vertical (Figure 8)

FIGURE 8

C. Tuck chin in (Figure 9)

FIGURE 9

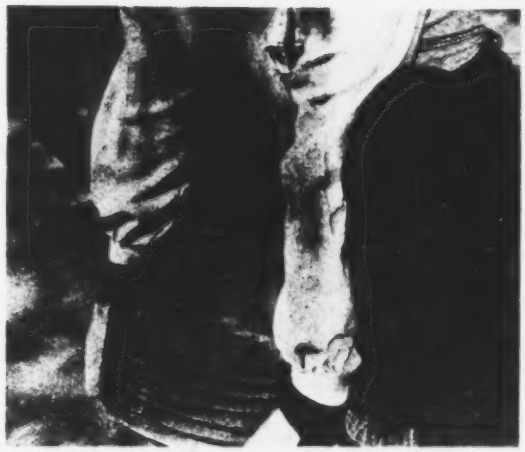
JOB SHEET #1

D. Grasp object with whole hand (Figure 10)

FIGURE 10

E. Tuck in elbows and arms; hold load close to body (Figure 11)

FIGURE 11



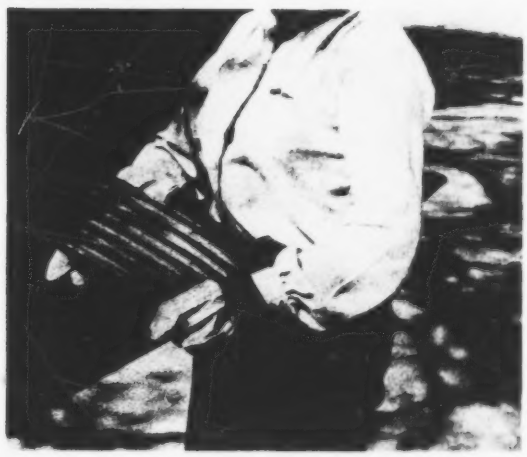
JOB SHEET #1

F. Keep body weight directly over feet (Figure 12)

FIGURE 12

G. Lift object (Figure 13)

FIGURE 13



SHOP SAFETY AND FIRST AID
UNIT I

JOB SHEET #2 — GIVE MOUTH-TO-MOUTH RESUSCITATION

Procedure

A. Clear victim's air passage

1. Place victim flat on back (Figure 14)

(NOTE: If it is necessary to roll victim over, try to roll the victim over all at once, keeping back and neck straight to avoid making any possible spinal injury worse.)

FIGURE 14

JOB SHEET #2

2. Remove all foreign objects from victim's mouth and throat (Figure 15)

   (NOTE: If there is an obstruction, carefully turn victim on side, tilt head down, and clean mouth out with your fingers. When obstruction is removed, carefully position victim onto back again.)

FIGURE 15

B. Kneel at the victim's side and lift up under victim's neck, tilting crown of head backwards (Figure 16)

   (NOTE: If possible, place a rolled piece of clothing under the victim's shoulders; this will help to secure the backward tilt of the head.)

FIGURE 16

JOB SHEET #2

C. Pull victim's lower jaw so the chin points straight up (Figure 17)

(NOTE: This will pull the tongue forward and open the air passage.)

FIGURE 17

D. Pinch victim's nostrils shut while still lifting up under the victim's neck (Figure 18)

FIGURE 18

JOB SHEET #2

E. Inhale deeply, and while making an airtight seal with your mouth over the victim's mouth, breathe into the victim's mouth until chest rises (Figure 19)

(CAUTION: Keep the victim's chin extended at all times.)

FIGURE 19

F. Remove your mouth from victim's mouth; listen for return flow of air (Figure 20)

FIGURE 20

SHOP SAFETY AND FIRST AID
UNIT I

TEST

NAME _____ SCORE _____

1. Match terms associated with shop safety to their correct definitions. Write the correct numbers in the blanks. Terms and definitions continue on the following page.

_____a.	State or condition of being safe; freedom from danger, risk, or injury	1. Flammable
_____b.	Any suddenly occurring, unintentional event that causes personal injury or property damage	2. Radiation
_____c.	Occupational Safety and Health Act; federal legislation designed to ensure safe and sanitary working conditions for employees	3. Extinguish
_____d.	Mine Safety and Health Administration; established by Department of Labor; organization that sees that mine operators promote safe and healthful working conditions and abide by mine safety and health regulations	4. OSHA
_____e.	Capable of being easily ignited and burning with extreme rapidity	5. Explosive
_____f.	Substance tending to explode	6. Solvent
_____g.	Capable of bursting into flames	7. Safety
_____h.	To cause to cease burning	8. Pressurized
_____i.	Stored under pressure greater than the pressure of the atmosphere	9. MSHA
_____j.	Source of danger; condition that can cause an accident	10. Hazard
_____k.	Combined processes of emission, transmission, and absorption of radiant energy	11. Accident
_____l.	Liquid substance capable of dissolving or dispersing one or more other substances	12. Combustible

TEST

_____m. Air-powered

_____n. Stunning, damaging, or shattering effect from a hard blow; possible injury to the brain

_____o. Colorless, odorless, very toxic gas contained in exhaust gas

_____p. Act of bringing a person back to full consciousness

_____q. Locking device used on equipment for securing parts and accessories in order to maintain safety while performing service, maintenance, or repairs

_____r. Immediate, temporary care given the victim of an accident or sudden illness until the services of a physician can be obtained

13. Concussion
14. Pneumatic
15. Carbon monoxide
16. Lockout
17. First aid
18. Resuscitation

2. State five reasons for practicing shop safety.

a. _____

b. _____

c. _____

d. _____

e. _____

3. State five personal safety rules.

a. _____

b. _____

c. _____

d. _____

e. _____

TEST

4. State ten rules for general shop safety.

a. _____

b. _____

c. _____

d. _____

e. _____

f. _____

g. _____

h. _____

i. _____

j. _____

5. Match colors of the safety color code to their correct applications. Write the correct numbers in the blanks. Answers may be used more than once. Applications continue on the following page. Color codes are listed again on the next page.

_____a. Designates caution

_____b. Designates information and caution against machines or equipment out of order or under repair

_____c. Indicate water pipes

_____d. Designates barricades

_____e. Designates dangerous machine parts that may cut, crush, shock, or otherwise injure

_____f. Identifies portable containers for flammable liquids

_____g. Indicate compressed-air pipes

_____h. Improves visibility

_____i. Designates danger and emergency

_____j. Designates location of safety equipment

1. Safety blue
2. Safety orange
3. Safety ivory
4. Safety red
5. Safety yellow
6. Black bands
7. Safety green
8. Yellow bands
9. Safety black and white (used individually or in combination)
10. Gray bands
11. Safety purple
12. Blue bands

TEST

_____k. Designates traffic flow

_____l. Indicate natural-gas and steam pipes

_____m. Marks obstacles such as low beams, protruding extensions, and steps

_____n. Designates location of first-aid equipment

_____o. Designates radiation hazard

_____p. Indicate vent-line pipes

_____q. Identifies emergency-stop bars, buttons, and switches on machinery

_____r. Designates storage areas

_____s. Designates information and caution on outside of large switch boxes and control covers

_____t. Designates out-of-order signs on equipment

_____u. Outlines work areas and traffic lanes

_____v. Designates housekeeping purposes

_____w. Designates tooling-action areas of machines and edges of tables and workbenches

_____x. Designates hazards such as pulleys, gears, rollers, cutting devices, and power jaws when enclosure doors or guards are open

_____y. Reflects light and shows the way

_____z. Designates safety cans, other containers of flammable liquids, and waste containers for explosive and/or combustible materials

_____aa. Identifies fire-fighting equipment

_____bb. Designates safety starter buttons, inside covers of shields, switch boxes, and parts of equipment that may cause electrical shock

_____cc. Designates flammable liquids with flash point of 80°F or lower

1. Safety blue
2. Safety orange
3. Safety ivory
4. Safety red
5. Safety yellow
6. Black bands
7. Safety green
8. Yellow bands
9. Safety black and white (used individually or in combination)
10. Gray bands
11. Safety purple
12. Blue bands

TEST

6. Select from the following list the components of the fire triangle. Write an "X" in the blank before each correct answer.

_____a. Fire

_____b. Water

_____c. Fuel

_____d. Heat

_____e. Oxygen

_____f. Carbon dioxide (CO_2)

7. Match classes of fires to their correct descriptions. Write the correct numbers in the blanks.

_____a. Fires that occur in or near electrical equipment such as motors, switches, circuit breakers, and electrical wiring

_____b. Fires that occur in ordinary combustible materials such as wood, paper, rags, and rubbish

_____c. Fires that are caused by or occur with combustible metals such as iron or magnesium

_____d. Fires that occur with flammable liquids such as gasoline, oil, grease, paint, thinners, and solvents

1. Class A
2. Class B
3. Class C
4. Class D

8. Match types of fire extinguishers to the classes of fires for which each is used. Write the correct numbers in the blanks. A blank may contain more than one number.

_____a. Used on class A fires *only*

_____b. Used on class A, B, and C fires

_____c. Used on class B and C fires

_____d. Used on class B fires *only*

_____e. Used on class D fires

1. Pressurized water
2. Carbon dioxide (CO_2)
3. Foam
4. Multipurpose dry chemical
5. Dry powder
6. Water pump tank

TEST

9. State five safety rules concerning flammable liquids.

   a. _____

   b. _____

   c. _____

   d. _____

   e. _____

10. Describe sources and effects of common breathing hazards. Write the information necessary to complete the following chart.

Hazards	Sources	Effects
Carbon monoxide	a. _____	b. _____
Nitrogen oxide and iron oxide	c. _____	d. _____
Trichloroethylene, petroleum solvents, carbon tetrachloride	e. _____	f. _____
Metallic substances, toxic vapors, carbon disulfide, naphtha, benzene	g. _____	h. _____
Asbestos fibers	i. _____	j. _____

TEST

11. Describe five procedures used to maintain a clean and orderly work area.

a. _____

_____

b. _____

_____

c. _____

_____

d. _____

_____

e. _____

_____

12. Arrange in order correct procedures for lifting a heavy object. Write a "1" for the first step, a "2" for the second step, and so on.

_____a. Keep body weight directly over feet

_____b. Tuck chin in

_____c. Hold load close to body

_____d. Keep back straight, nearly vertical

_____e. Tuck in elbows and arms

_____f. Lift object

_____g. Step up to object with feet apart; place one foot beside object and one behind

_____h. Grasp object with whole hand

13. Name two reasons why knowledge of first aid is important.

a. _____

b. _____

TEST

14. Discuss reasons why first-aid skills are needed.

a. _____

b. _____

c. _____

15. Arrange in order immediate steps to follow when giving first aid to an accident victim. Write a "1" before the first step, a "2" before the second step, and so on.

_____a. Observe pupil reaction of the eyes

_____b. Check breathing

_____c. Begin definite first-aid treatment for symptoms

_____d. Observe overall emergency

_____e. Check pulse or heartbeat

_____f. If victim is conscious, check alertness level by asking questions about physical status

16. Select from the following list factors to consider in first-aid treatment of shock. Write an "X" in the blank before each correct answer.

_____a. Get medical help as soon as possible

_____b. Use good judgment in giving liquids; consider the victim's condition and the cause of shock

_____c. Help victim sit up immediately

_____d. Cover victim to prevent loss of body heat and to stabilize blood circulation

_____e. Cover victim to keep dirt off

_____f. Maintain adequate supply of oxygen

_____g. Give victim a drink immediately

_____h. Keep victim lying down

TEST

17. Classify types of burns by degree according to description. In the blanks below, write a "1" for first-degree burns, a "2" for second-degree burns, or a "3" for third-degree burns.

_____a. Blistering

_____b. Rapid healing

_____c. Mottled or red areas

_____d. Charred or white appearance

_____e. Damage extending into first layer of tissue

_____f. Redness or discoloration

_____g. Mild swelling or pain

_____h. Pain greater than first degree

_____i. Considerable swelling

_____j. Deep tissue destruction

_____k. Wet appearance of burned area due to loss of plasma

_____l. Less pain due to nerve destruction

18. Match first- , second- , and third-degree burns to their correct first-aid treatments. In the blanks below, write a "1" for first-degree burns, a "2" for second-degree burns, or a "3" for third-degree burns.

_____a. Cover burns with thick sterile dressings; do not immerse in water; do not remove any tissue or burned clothing; transport victim to hospital as quickly as possible

_____b. Apply cold water or submerge burned area in cold water; apply a dry dressing if necessary

_____c. Submerge the burned area in cold water (not ice water) until pain eases; blot dry gently and apply dry, sterile dressings; do not break blisters; do not use any ointments, sprays, or home remedies on burned area

TEST

19. Describe steps to follow to control bleeding by direct pressure.

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

20. Arrange in order steps to follow for mouth-to-mouth resuscitation. Write a "1" before the first step, a "2" before the second step, and so on.

_____a. Pinch victim's nostrils shut

_____b. Clear victim's air passage

_____c. Inhale deeply; breathe into victim's mouth

_____d. Remove your mouth from victim's mouth; listen for return flow of air

_____e. Extend victim's chin by lifting up under neck

(NOTE: Test questions 21-24 are the assignment and job sheets. They are an important part of this test. If they have not been completed, check with your instructor.)

21. Complete a safety-pledge form.

22. Analyze accident case studies.

23. Evaluate situations involving hazards.

24. Demonstrate the ability to

    a. Lift a heavy object properly.

    b. Give mouth-to-mouth resuscitation.

SHOP SAFETY AND FIRST AID
UNIT I

ANSWERS TO TEST

1.	a.	7	f.	5	k.	2	p.	18
	b.	11	g.	12	l.	6	q.	16
	c.	4	h.	3	m.	14	r.	17
	d.	9	i.	8	n.	13		
	e.	1	j.	10	o.	15		

2. Answer should include any five of the following

   a. Prevent physical harm to yourself and others

   b. Prevent loss or damage of equipment or materials

   c. Avoid loss of work

   d. Avoid possible loss of pay

   e. Lower cost to employer

   f. Lower insurance rates

   g. Prevent loss of job

   h. Prevent hardship on family

   i. Provide regular job schedules

   j. Keep insurance costs down

   k. Affect attitude and morale

   l. Increase productivity

3. Answer should include any five of the following

   a. Wear clothing that is appropriate to the job being performed

   b. Wear safety glasses and other safety equipment where required

   c. Be alert, and conduct yourself in a manner to ensure safe practices

ANSWERS TO TEST

d. Do not jump onto or off equipment

e. Remove ties, loose sleeves, and other loose clothing when working around machine tools or rotating equipment

f. Remove rings and other jewelry when working

g. Use soap and water frequently to prevent skin disease

h. Confine long hair before working around running equipment

i. Be familiar with location of first-aid equipment

j. Be familiar with location and type of available fire extinguishers

4. Answer should include any ten of the following

a. Keep work area clean

b. Store flammable materials in metal containers with self-sealing lids

c. Keep all tools sharp, clean, and in good working order

d. Retain guards, tool rests, and safety devices on all equipment

e. Never leave an operating machine unattended

f. Disconnect power lock and tag out machine tools before performing maintenance

g. Use correct, properly fitting wrenches on nuts and bolts

h. Clean up spilled liquids immediately

i. Do not use compressed air to clean yourself or your clothing

j. Be conscious of others' safety

k. Be sure that others are at a safe distance when you are operating equipment

l. Do not lean against machines while operating them

m. Avoid startling or distracting others who are operating equipment

n. Report defective tools and equipment to your supervisor

o. Report all accidents to your supervisor, regardless of nature or severity

ANSWERS TO TEST

p. Maintain safety rules and limitations on all equipment according to specifications and manufacturer's regulations

q. Develop a positive attitude toward safety; do not become overconfident; stay alert

r. Keep all tools and equipment properly stored when not in use

s. Use proper grounds on all electrical equipment

t. Use jack stands when working under equipment

u. Use solvents and cleaning fluids only after determining what their properties are, what kind of work they do, and how they should be used

v. Never operate equipment until you have been properly checked out on its operation and safety regulations

w. Use caution when operating mobile equipment, including hoists, cranes, and winches

x. Never weld or cut galvanized metal without good ventilation

y. Never operate engines in unventilated shops

z. Be sure to use lockouts and safety levers as prescribed by OSHA regulations while performing maintenance and repairs

5.

a.	5	i.	4	q.	4	y.	3
b.	1	j.	7	r.	9	z.	5
c.	10	k.	9	s.	1	aa.	4
d.	9	l.	8	t.	1	bb.	2
e.	2	m.	5	u.	5	cc.	5
f.	4	n.	7	v.	9		
g.	12	o.	11	w.	3		
h.	3	p.	6	x.	2		

6. c, d, e

ANSWERS TO TEST

7. a. 3
   b. 1
   c. 4
   d. 2

8. a. 1, 6
   b. 4
   c. 2
   d. 3
   e. 5

9. Answer should include any five of the following
   a. Know the location and type of fire extinguishers to use for flammable liquids
   b. Store all flammable liquids in approved safety containers
   c. Use only approved cleaning solvents to clean parts
   d. Do not fuel a running or hot gasoline engine
   e. Do not operate an engine that has a gasoline leak
   f. Change oil- or gasoline-soaked clothing immediately
   g. Wipe up spilled oil, cleaning solvents, and gasoline immediately, and dispose of rags in the proper containers
   h. Store flammable liquids only in prescribed locations
   i. Clearly mark all flammable liquids and storage areas

10. Description should include the following
    a. Engines
    b. Displaces oxygen in the blood; causes dizziness, drowsiness, headaches, and sudden death
    c. Welding
    d. Causes accumulation of fluid in the lungs

ANSWERS TO TEST

e. Parts cleaning

f. Causes headaches and lung, kidney, and liver damage

g. Paint and glue products

h. Has narcotic effect; long-term exposure may cause damage to lungs, liver, kidneys, and bone marrow

i. Construction, insulation, brake work

j. Causes lung cancer

11. Description should include any five of the following

a. Arrange machinery and equipment to permit safe, efficient work practices and ease in cleaning

b. Stock materials and supplies in proper places

c. Store tools and accessories in proper places

d. Keep work area clean and clear of hazards

e. Dispose of combustible materials properly

f. Keep cleaning supplies and housekeeping equipment in a central location

12.

a.	7	e.	5
b.	3	f.	8
c.	6	g.	1
d.	2	h.	4

13. Answer should include any two of the following

a. May mean the difference between life and death

b. May mean the difference between temporary or permanent injuries

c. Trains one in what to do and what not to do in an emergency

ANSWERS TO TEST

14. Discussion should include the following

    a. Accidents are the number-one cause of death

    b. There may not be time to wait for professional medical help after an accident

    c. Safety awareness needs to be promoted at work

15.

a.	4	d.	1
b.	2	e.	3
c.	6	f.	5

16. a, b, d, f, h

17.

a.	2	d.	3	g.	1	j.	3
b.	1	e.	2	h.	2	k.	2
c.	2	f.	1	i.	2	l.	3

18. a. 3

    b. 1

    c. 2

19. Description should include the following

    a. Apply dressing (prepared gauze, clean handkerchief, clean articles of clothing) to area, using firm pressure with hand

    b. Check frequently to see whether bleeding has stopped or slowed

    c. If bleeding is still active, apply a pressure bandage by holding the dressing in place with one hand, wrapping bandage directly over and around the injured area, and tying the knot over the wounded area

    d. If injured area is a limb, elevate the limb, if possible, above the level of the victim's heart

    e. If bleeding continues, apply pressure on the main artery that supplies blood to the injured area

ANSWERS TO TEST

20. a. 3 d. 5
    b. 1 e. 2
    c. 4

21. Evaluated to the satisfaction of the instructor

22. Evaluated to the satisfaction of the instructor

23. Evaluated to the satisfaction of the instructor

24. Performance skills evaluated to the satisfaction of the instructor

HAND TOOLS AND MISCELLANEOUS TOOLS
UNIT II

UNIT OBJECTIVE

After completing this unit, the student should be able to identify all types of hand tools, miscellaneous tools, and special tools used for servicing and repairing engines. The student will show this knowledge by completing job sheets and unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. State the purpose of tools.
2. Identify types of screwdrivers.
3. Identify types of pliers.
4. Identify types of hammers.
5. Identify types of wrenches.
6. Label the components of a socket set.
7. Identify types of sockets.
8. Identify types of special-purpose sockets.
9. Identify types of punches.
10. Identify types of chisels.
11. Label types of files.
12. Identify types of file teeth.
13. Label types of parts-cleaning tools.
14. Label tools used to service batteries.
15. Label tools used to service the starting system.
16. Label tools used to service the charging system.
17. Label tools used to service the ignition system.

OBJECTIVE SHEET

18. Label tools used to service the fuel system.
19. Label tools used to service the exhaust system.
20. Label tools used to service the cooling system.
21. Label tools used to service the brake system.
22. Label tools used to service the front-end system.
23. Label tools used to service the drive line.
24. Identify tools used in engine repair.
25. Identify tools used in lubrication service.
26. Identify miscellaneous and special tools and equipment.
27. Demonstrate the ability to
    a. Fit a screwdriver.
    b. Reshape a cold chisel.
    c. Cut flat metal with a cold chisel.
    d. Dress a grinding wheel.
    e. Drawfile a flat surface.
    f. Sharpen a twist drill.
    g. Drill holes with a drill press.
    h. Draw a twist drill hole to correct center.
    i. Check torque wrench for accuracy.
    j. Replace a hammer handle.

HAND TOOLS AND MISCELLANEOUS TOOLS
UNIT II

SUGGESTED ACTIVITIES

I. Suggested activities

A. Order tool catalogs to supplement unit.

B. Make or obtain transparencies.

(NOTE: Transparencies are available from AGC and CIMC.)

C. Provide students with objective sheet.

D. Discuss unit and specific objectives.

E. Provide students with information and job sheets.

F. Discuss information sheet.

G. Demonstrate and discuss procedures outlined in job sheets.

H. Have students demonstrate the ability to use shop tools correctly and safely.

I. Tell students to buy good grades of tools and not to be impressed with prices of cheaper grades.

J. Make sure that all power tools have properly mounted safety guards, and check to be sure that guards are being used.

K. Give test.

L. Complete appropriate section of competency profiles.

(NOTE: Competency profiles are available from AGC and CIMC.)

II. Instructional materials

A. Objective sheet

B. Suggested activities

C. Information sheet

D. Transparency masters

1. TM #1 — Types of Screwdrivers

SUGGESTED ACTIVITIES

2. TM #2 — Types of Pliers
3. TM #3 — Types of Hammers
4. TM #4 — Types of Wrenches
5. TM #5 — Types of Wrenches (Continued)
6. TM #6 — Components of a Socket Set
7. TM #7 — Types of Sockets
8. TM #8 — Special-Purpose Sockets
9. TM #9 — Types of Punches
10. TM #10 — Types of Chisels
11. TM #11 — Types of Files
12. TM #12 — Types of File Teeth
13. TM #13 — Types of Parts-Cleaning Tools
14. TM #14 — Battery Service Tools
15. TM #15 — Starting-System Service Tools
16. TM #16 — Charging-System Service Tools
17. TM #17 — Ignition-System Service Tools
18. TM #18 — Fuel-System Service Tools
19. TM #19 — Exhaust-System Service Tools
20. TM #20 — Cooling-System Service Tools
21. TM #21 — Brake-System Service Tools
22. TM #22 — Brake-System Service Tools (Continued)
23. TM #23 — Front-End-System Service Tools
24. TM #24 — Drive-Line Service Tools
25. TM #25 — Engine-Repair Tools

SUGGESTED ACTIVITIES

26. TM #26 — Engine-Repair Tools (Continued)
27. TM #27 — Lubrication Service Tools
28. TM #28 — Miscellaneous Tools
29. TM #29 — Miscellaneous Tools (Continued)
30. TM #30 — Miscellaneous Tools (Continued)
31. TM #31 — Miscellaneous Tools (Continued)
32. TM #32 — Miscellaneous Tools (Continued)
33. TM #33 — Miscellaneous Tools (Continued)
34. TM #34 — Miscellaneous Tools (Continued)
35. TM #35 — Miscellaneous Tools (Continued)
36. TM #36 — Miscellaneous Tools (Continued)

E. Job sheets

1. Job Sheet #1 — Fit a Screwdriver
2. Job Sheet #2 — Reshape a Cold Chisel
3. Job Sheet #3 — Cut Flat Metal with a Cold Chisel
4. Job Sheet #4 — Dress a Grinding Wheel
5. Job Sheet #5 — Drawfile a Flat Surface
6. Job Sheet #6 — Sharpen a Twist Drill
7. Job Sheet #7 — Drill Holes with a Drill Press
8. Job Sheet #8 — Draw a Twist Drill Hole to Correct Center
9. Job Sheet #9 — Check Torque Wrench for Accuracy
10. Job Sheet #10 — Replace a Hammer Handle

F. Test

G. Answers to test

SUGGESTED ACTIVITIES

III. Unit references

A. Armstrong, Ivan J. *Auto Mechanics,* Vol. I. Stillwater, Oklahoma: State Department of Vocational and Technical Education/Curriculum and Instructional Materials Center, 1980.

B. Hendrix, Laborn J. "Bud." *Millwright Instructional Materials.* Stillwater, Oklahoma: State Department of Vocational and Technical Education/Curriculum and Instructional Materials Center and The Associated General Contractors of America, 1980.

HAND TOOLS AND MISCELLANEOUS TOOLS
UNIT II

INFORMATION SHEET

I. Purpose of tools — To allow the mechanic to perform a variety of service procedures quickly, safely, and efficiently

II. Types of screwdrivers (Transparency #1)

- A. Standard or common
- B. Phillips
- C. Clutch
- D. Reed and Prince
- E. Offset

III. Types of pliers (Transparency #2)

- A. Slip-joint
- B. Channel lock
- C. Needlenose
- D. Diagonal side cutter
- E. Lock grip

IV. Types of hammers (Transparency #3)

- A. Ball-peen
- B. Sledgehammer
- C. Plastic tip
- D. Rubber
- E. Brass

V. Types of wrenches (Transparencies #4 and #5)

- A. Open end
- B. Box end

INFORMATION SHEET

C. Combination

D. Obstruction box end

E. Flex head

F. Tubing

G. Adjustable

H. Pipe

VI. Componenets of a socket set (Transparency #6)

A. Break-over handle

B. Ratchet handle

C. Speed handle

D. Extension

E. Sliding T-handle

F. Universal joint

G. Socket

VII. Types of sockets (Transparency #7)

A. Six point

B. Twelve point

C. Deep well

D. Universal

E. Standard

VIII. Types of special-purpose sockets (Transparency #8)

A. Phillips

B. Standard

C. Clutch

INFORMATION SHEET

D. Allen or hex head

E. Triple-square cap

F. Shock absorber

G. Crowfoot

H. Drag link

I. Prong nut or dash nut

J. Oil sender

IX. Types of punches (Transparency #9)

A. Center

B. Pin

C. Starting

D. Drift

E. Lining-up

X. Types of chisels (Transparency #10)

A. Cold

B. Cape

C. Roundnose

D. Diamond-point

XI. Types of files (Transparency #11)

A. Flat

B. Round

C. Triangular (three-square)

D. Square

INFORMATION SHEET

E. Cant saw

F. Half round

G. Knife

H. Slitting

XII. Types of file teeth (Transparency #12)

A. Single-cut

B. Double-cut

C. Curved

D. Rasp-cut

XIII. Types of parts-cleaning tools (Transparency #13)

A. Wire brush

B. Carbon scraper

C. Gasket scraper

D. Parts-cleaning brush

XIV. Tools used to service batteries (Transparency #14)

A. Cable puller

B. Terminal pliers

C. Post and cable cleaner

D. Cable spreader

E. Lifting strap

F. Battery filler

G. Hydrometer

XV. Tools used to service the starting system (Transparency #15)

A. Growler

B. Amp-volt tester

INFORMATION SHEET

C. Bushing driver set

D. Remote-control starter switches

XVI. Tools used to service the charging system (Transparency #16)

A. Amp-volt tester

B. Ohmmeter

C. Diode tester

D. Continuity light

XVII. Tools used to service the ignition system (Transparency #17)

A. Insulated pliers

B. Spark plug ratchet and socket

C. Spark plug gauge

D. Feeler gauge

E. Spring gauge

F. Dwell meter

G. Timing light

H. Distributor wrench

XVIII. Tools used to service the fuel system (Transparency #18)

A. Fuel-pump tester

B. Flaring tool

C. Tubing cutter

XIX. Tools used to service the exhaust system (Transparency #19)

A. Hand pipe cutter

B. Power chisel

C. Pipe-expanding tool

INFORMATION SHEET

D. Straightening cone

E. Chain wrench

F. Electric pipe-joint heater

XX. Tools used to service the cooling system (Transparency #20)

A. Hose-clamp pliers

B. Radiator pressure tester

C. Antifreeze tester

D. Belt-tension gauge

E. Fan wrench

F. Radiator hose remover

XXI. Tools used to service the brake system (Transparencies #21 and #22)

A. Cylinder hone

B. Cylinder clamp

C. Adjusting tool

D. Spring pliers

E. Disc brake pad spreader

F. Brake shoe adjusting gauge

G. Bleeder wrench

H. Bleeder tube

I. Grease cap remover

XXII. Tools used to service the front-end system (Transparency #23)

A. Toe-in adjusting wrench

B. Tie-rod-end remover

C. Ball-joint remover

D. Dust cover remover

E. Seal driver set

INFORMATION SHEET

XXIII. Tools used to service the drive line (Transparency #24)

- A. Automatic transmission pressure gauge set
- B. Flywheel turner
- C. Clutch aligning set
- D. Differential adjusting tool
- E. Snap-ring pliers
- F. Universal-joint press set
- G. Transmission bushing puller
- H. Transmission bushing driver
- I. Dial indicator

XXIV. Tools used in engine repair (Transparencies #25 and #26)

- A. Ridge reamer
- B. Cylinder deglazing hone
- C. Cylinder taper gauge
- D. Piston ring groove cleaner
- E. Piston ring expander
- F. Piston ring compressor
- G. Valve spring compressor
- H. Valve spring pressure tester

XXV. Tools used in lubrication service (Transparency #27)

- A. Grease gun
- B. Grease fitting tool
- C. Oil can (trigger type)
- D. Oil filter removing tools
- E. Oil spout
- F. PCV tester
- G. Transmission filler funnel

INFORMATION SHEET

XXVI. Miscellaneous and special tools and equipment (Transparencies #28-#36)

A. Tap and die set

B. Drills

C. Allen wrenches

D. Lug wrench

E. Metal-cutting shears

F. Hacksaw

G. Snap-ring pliers

H. Universal nut-cracker

I. Stud remover

J. Torque wrenches

(NOTE: A torque wrench may measure in either inch-pounds or foot-pounds and have one of three types of scales: micrometer, dial-indicating, or beam-type.)

K. Pry bar

L. Inspection mirror

M. C-clamp

N. Parallel clamp

O. Machinist's clamp

P. Bench vise

Q. Bench grinder

R. Drill press

S. Hand drill

T. Arbor press

U. Portable grinder

V. Air compressor

INFORMATION SHEET

W. Tire valve tool

X. Tire pressure gauges

Y. Air nozzle

Z. Impact hammer

AA. Impact wrench

BB. Puller set (bearing, gear, and wheel)

CC. Hydraulic hand jack

DD. Heavy-duty floor jack

EE. Creeper

FF. Jack stands

GG. Engine stand

HH. Chain hoist

II. Hydraulic lift

JJ. Engine lift adapters

1. Cylinder-head bolt

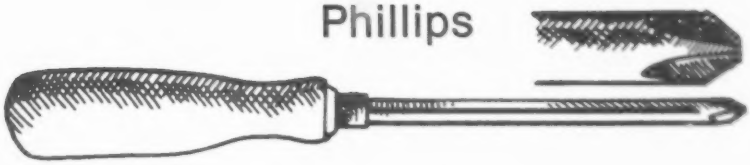
2. Engine or transmission support

KK. Battery charger

Types of Screwdrivers

Standard or Common

Phillips



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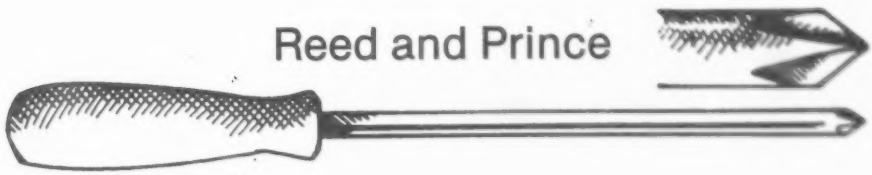


Clutch

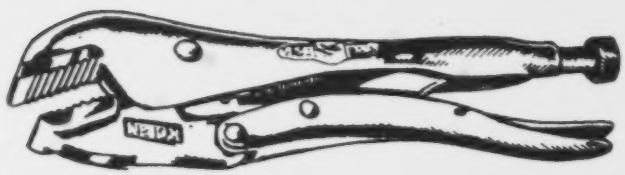
Offset

Types of Pliers

Slip-Joint

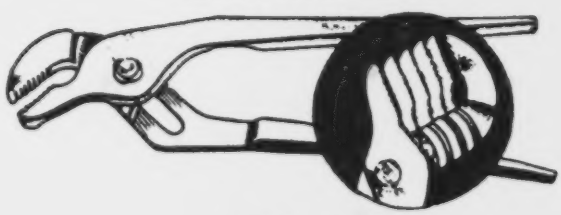
Needlenose

Lock Grip



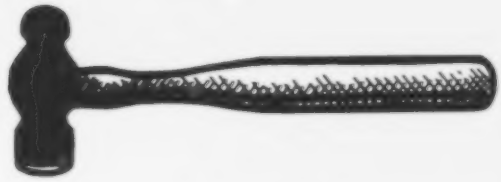
Diagonal Side Cutter

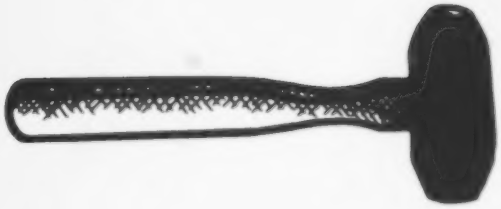
Channel Lock



Types of Hammers

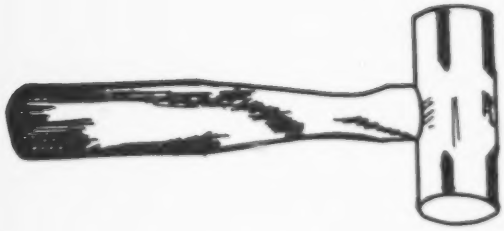
Ball-Peen





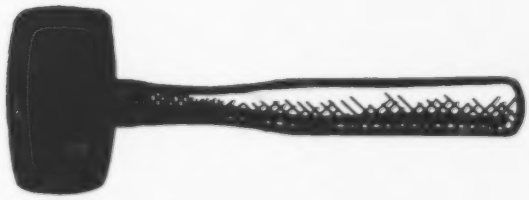
Brass

Plastic Tip



Sledgehammer

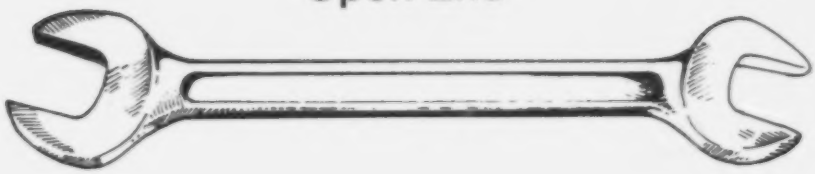
Rubber



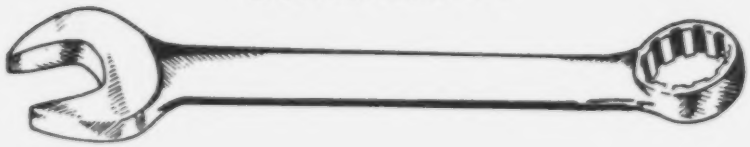
Types of Wrenches

Box End

Open End



Combination

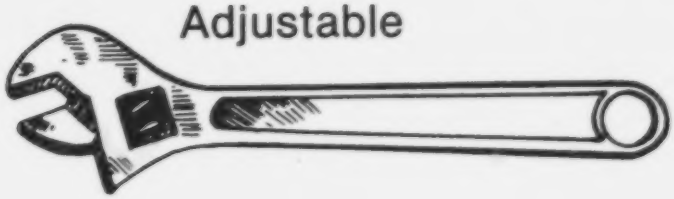


Obstruction Box End

Types of Wrenches
(Continued)

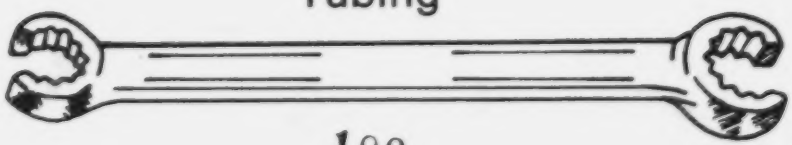
Flex Head

Adjustable



Pipe

Tubing



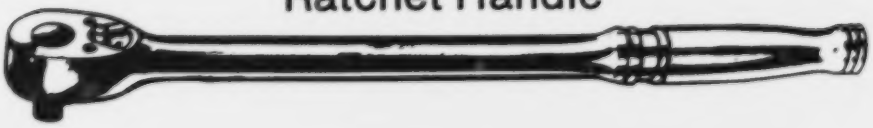
Components of a Socket Set

Socket

Speed Handle

Sliding T-Handle

Ratchet Handle



Break-Over Handle

Universal Joint

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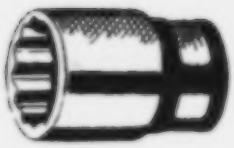
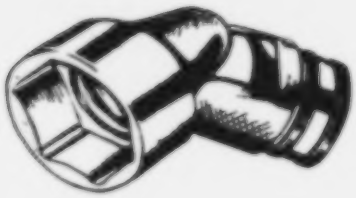
Extension

Types of Sockets



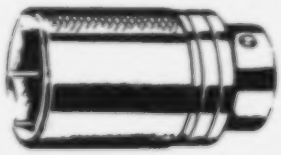
Standard



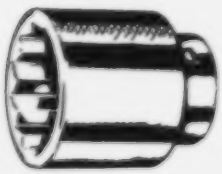
Universal

Deep Well

Six Point



Twelve Point



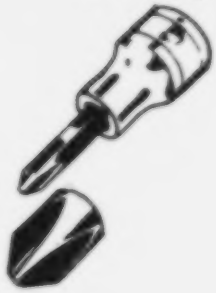
Special-Purpose Sockets

Shock Absorber

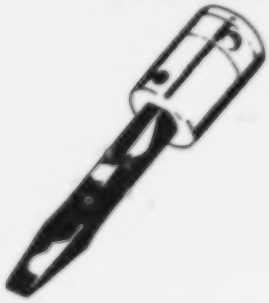
Crowfoot

Drag Link

Phillips



Standard



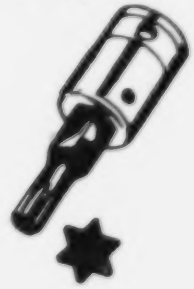
Prong Nut or Dash Nut

Clutch

Oil Sender

Allen or Hex Head

Triple-Square Cap



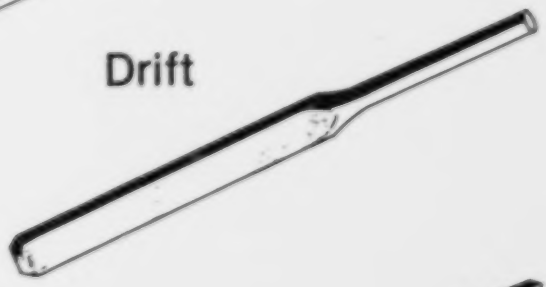
Types of Punches

Pin

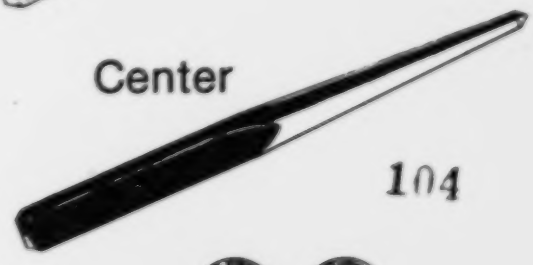
Starting

Lining-Up

Drift



Center



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Types of Chisels

Diamond-Point

Roundnose

Cape

Cold

Types of Files

Flat

Round

Half Round

Triangular (Three-Square)

Knife

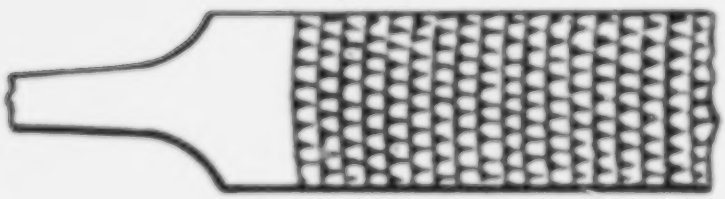
Square

Slitting

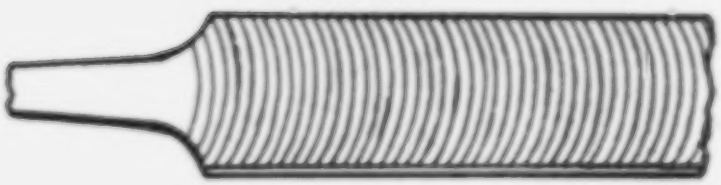
Cant Saw

Types of File Teeth

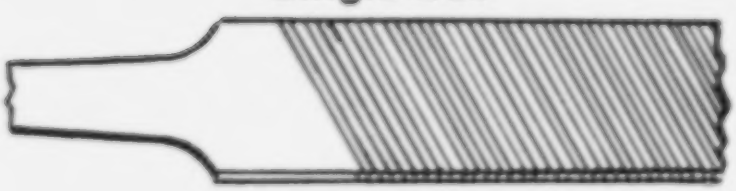
Rasp-Cut



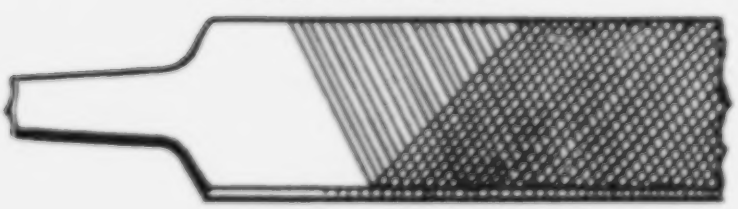
Curved



Single-Cut



Double-Cut

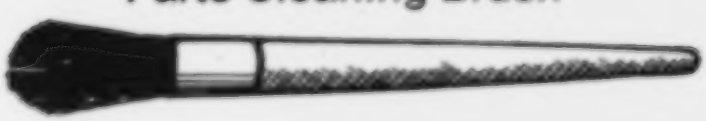


Types of Parts-Cleaning Tools

Carbon Scraper

Wire Brush

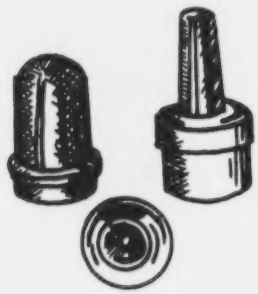
Parts-Cleaning Brush



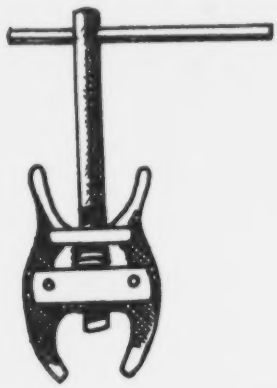
Gasket Scraper

Battery Service Tools

Post and Cable Cleaner

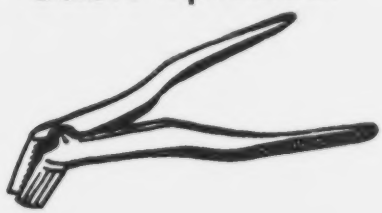


Cable Puller



Terminal Pliers

Cable Spreader



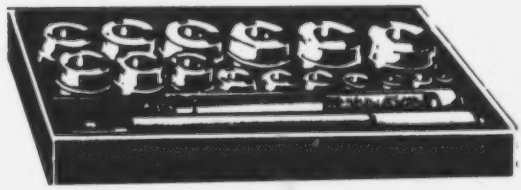
Lifting Strap

Battery Filler

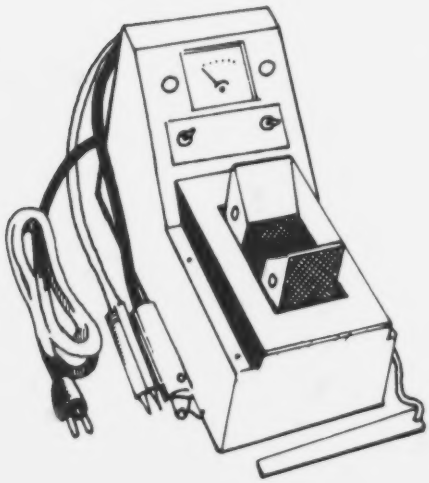
Hydrometer

Starting-System Service Tools

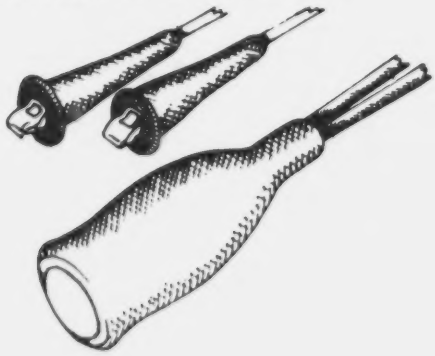
Bushing Driver Set



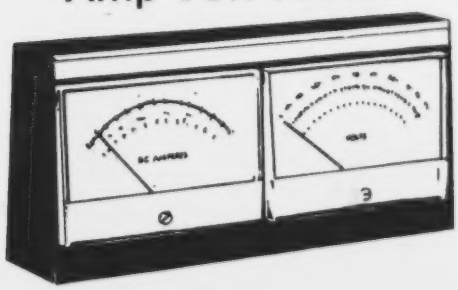
Growler



Remote-Control Starter Switches

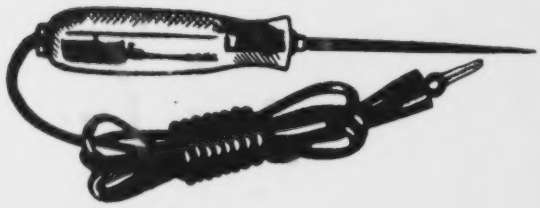


Amp-Volt Tester

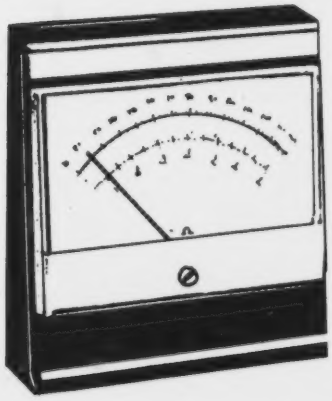


Charging-System Service Tools

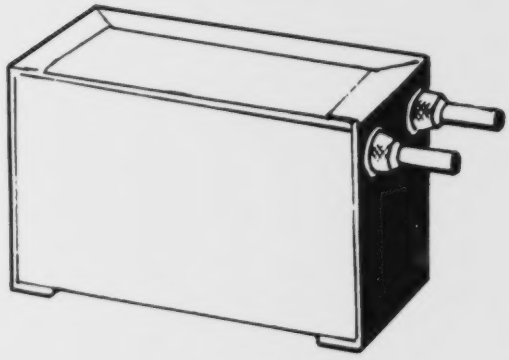
Continuity Light



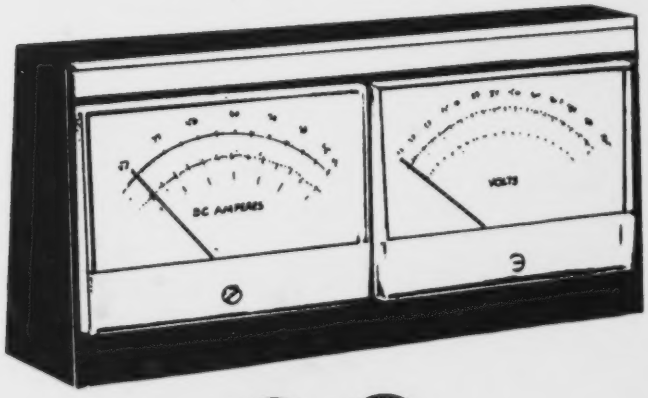
Ohmmeter



Diode Tester



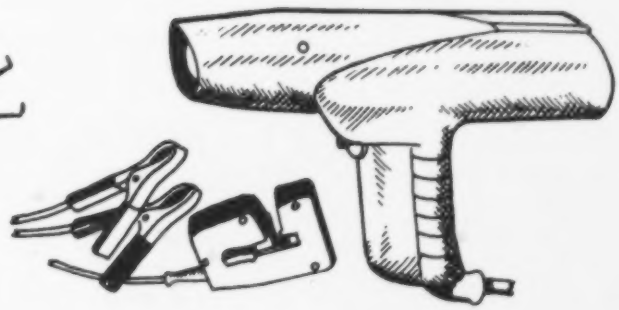
Amp-Volt Tester



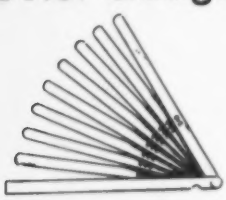
Ignition-System Service Tools

Spark Plug Gauge

Timing Light

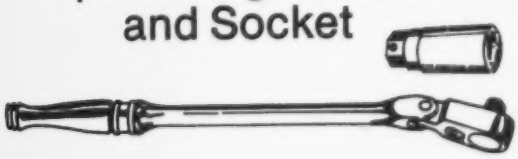


Feeler Gauge



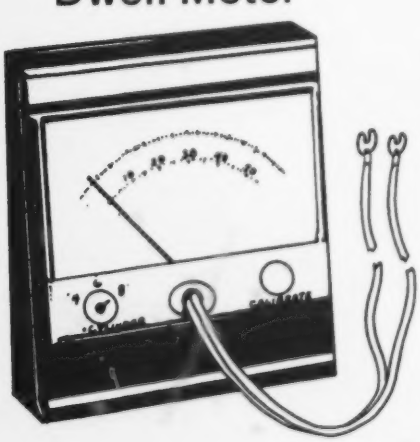
Spring Gauge

Spark Plug Ratchet and Socket



Insulated Pliers

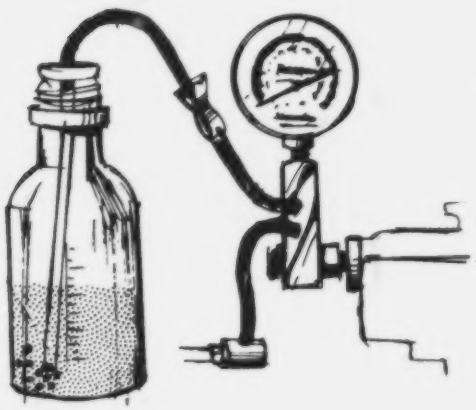
Dwell Meter



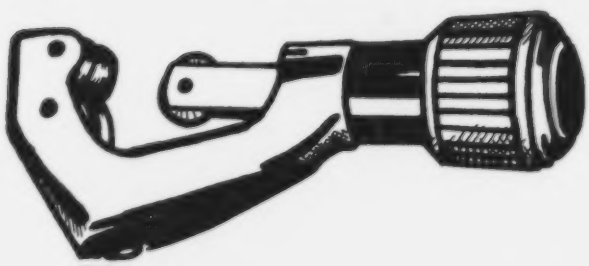
Distributor Wrench

Fuel-System Service Tools

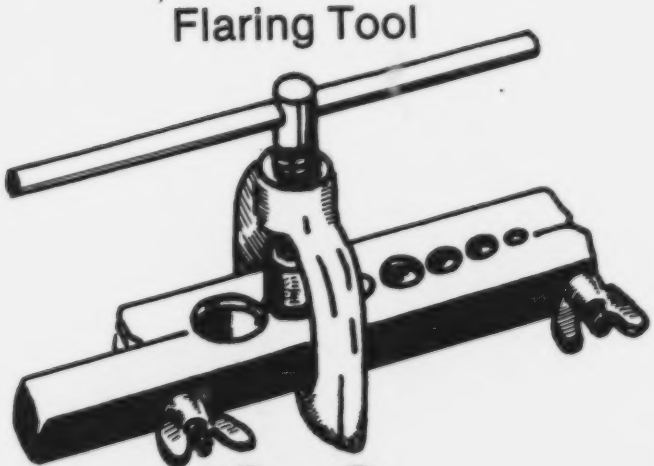
Fuel-Pump Tester



Tubing Cutter

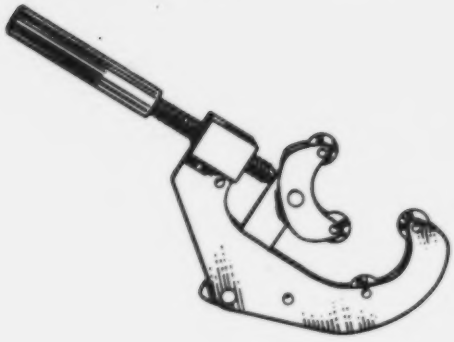


Flaring Tool

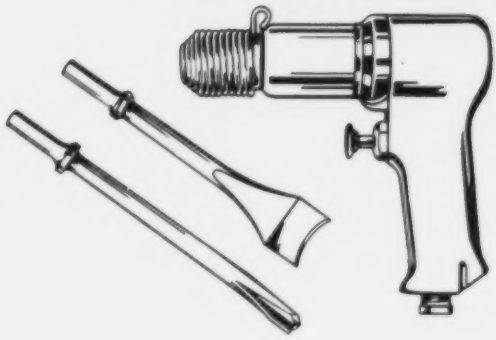


Exhaust-System Service Tools

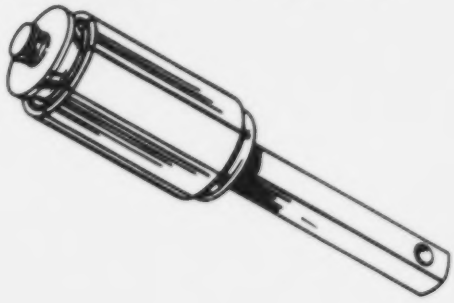
Hand Pipe Cutter



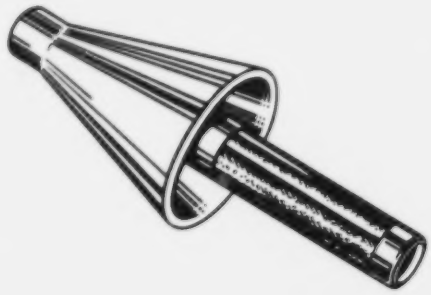
Power Chisel



Pipe-Expanding Tool

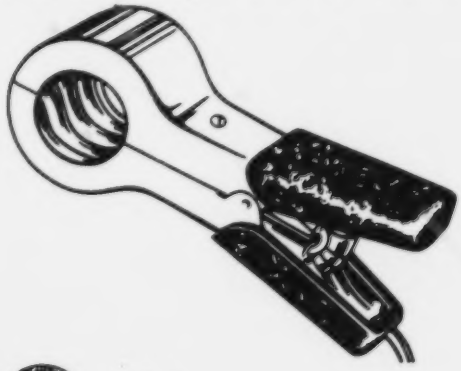


Straightening Cone



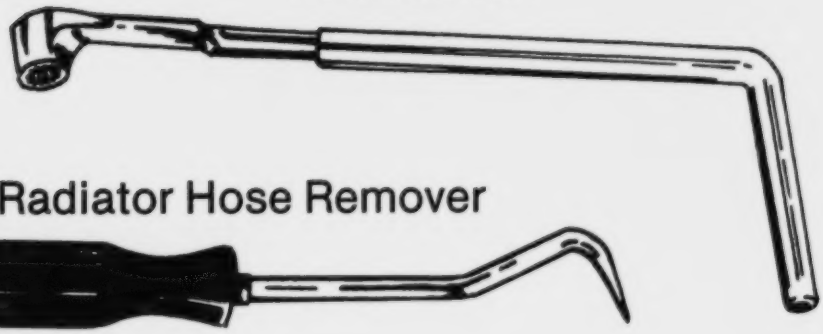
Chain Wrench

Electric Pipe-Joint Heater



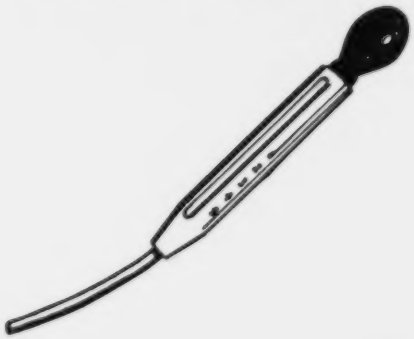
Cooling-System Service Tools

Fan Wrench

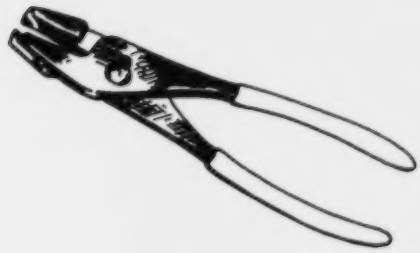


Radiator Hose Remover

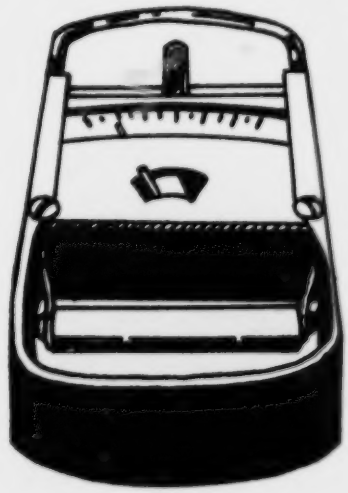
Antifreeze Tester



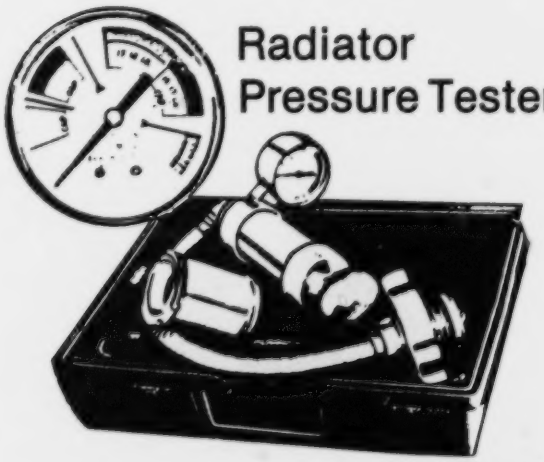
Hose-Clamp Pliers



Belt-Tension Gauge



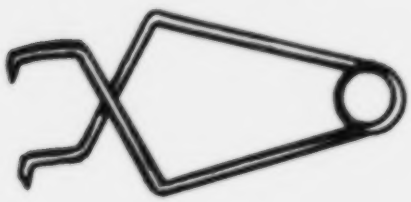
Radiator
Pressure Tester



Brake-System Service Tools

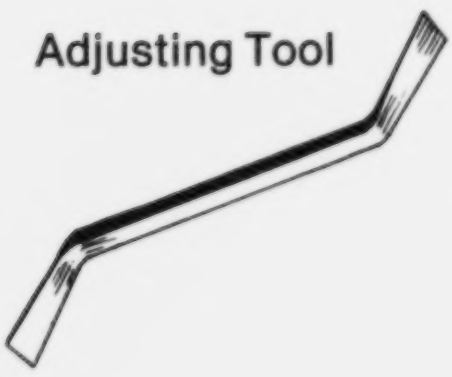
Bleeder Wrench

Cylinder Clamp

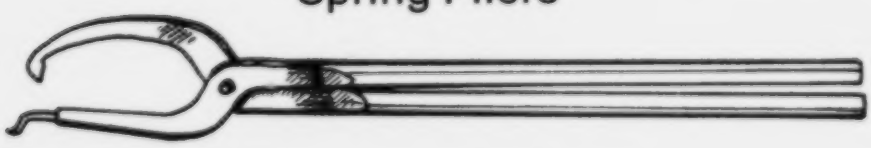


Cylinder Hone

Adjusting Tool

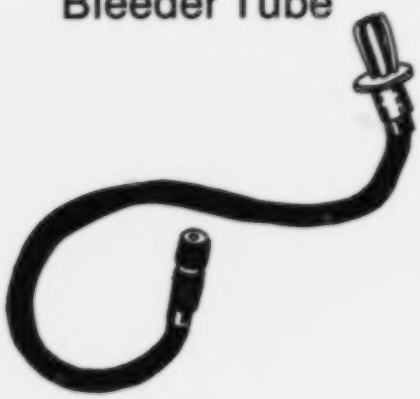


Spring Pliers

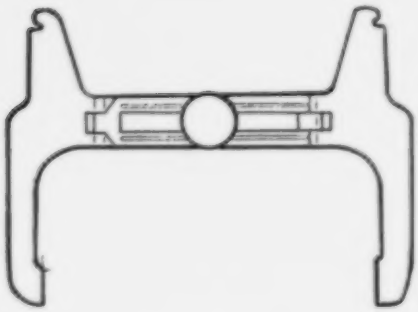


Brake-System Service Tools
(Continued)

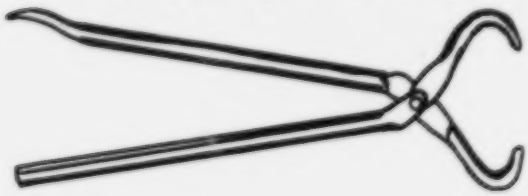
Bleeder Tube



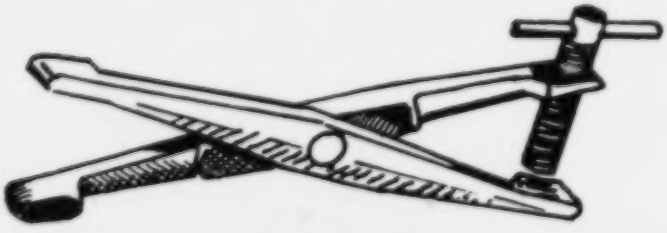
Brake Shoe
Adjusting Gauge



Grease Cap Remover



Disc Brake Pad Spreader



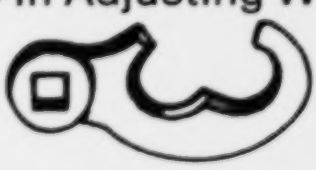
Front-End System Service Tools

Ball-Joint Remover

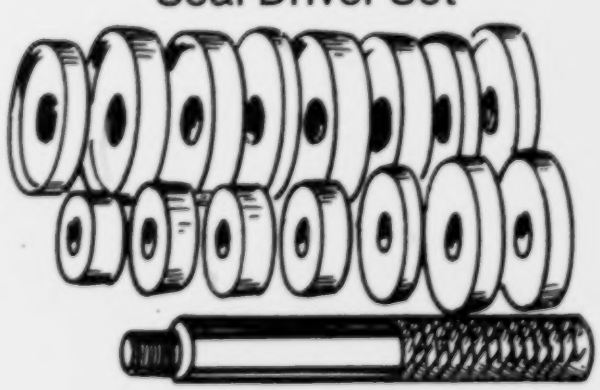
Tie-Rod-End Remover

Dust Cover Remover

Toe-In Adjusting Wrench

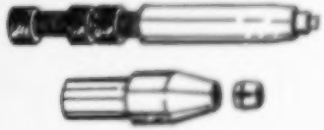


Seal Driver Set

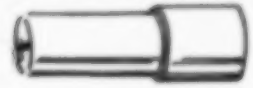


Drive-Line Service Tools

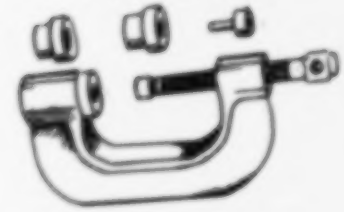
Clutch Aligning Set



Transmission Bushing Driver



Universal-Joint Press Set

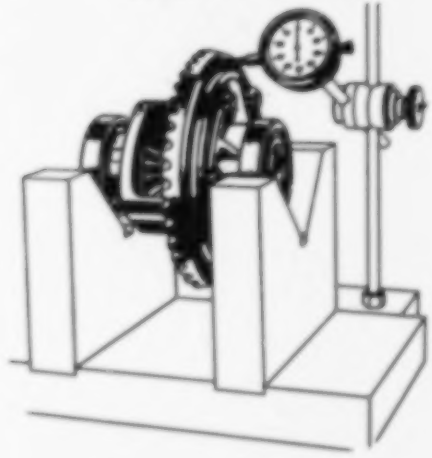


Flywheel Turner

Transmission Bushing Puller

Differential Adjusting Tool

Dial Indicator



Automatic Transmission Pressure Gauge Set

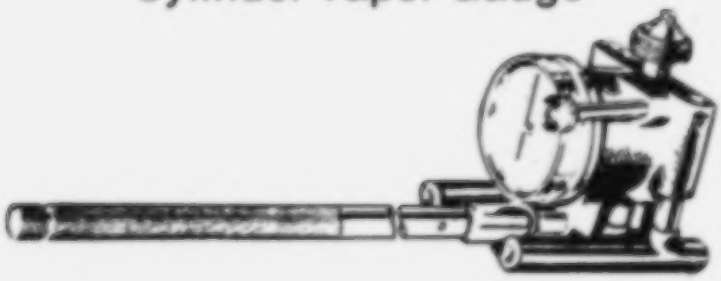
Snap-Ring Pliers

TM #24

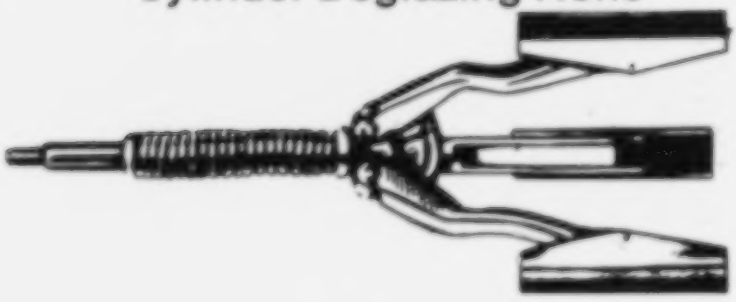
HEM - 137-A

Engine-Repair Tools

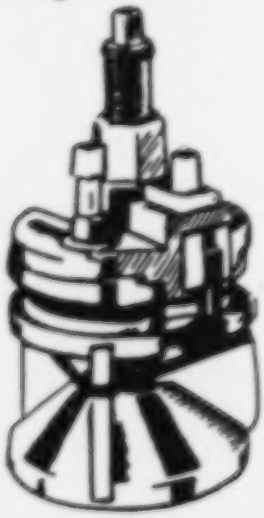
Cylinder Taper Gauge



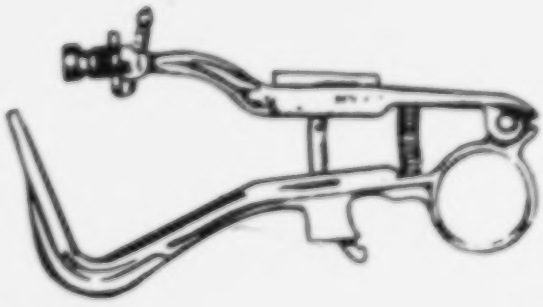
Cylinder Deglazing Hone



Ridge Reamer



Piston Ring Groove Cleaner

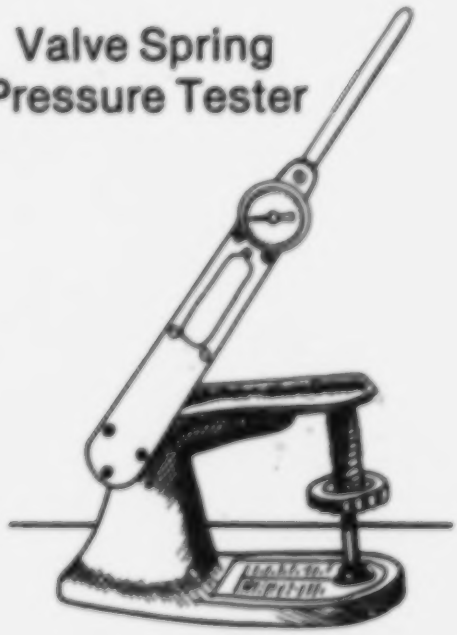


Engine-Repair Tools
(Continued)

Piston Ring Expander

Valve Spring Compressor

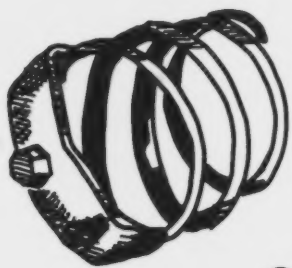
Valve Spring
Pressure Tester



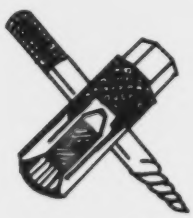
Piston Ring Compressor

Lubrication Service Tools

Oil Filter Removing Tools



Grease-Fitting Tool

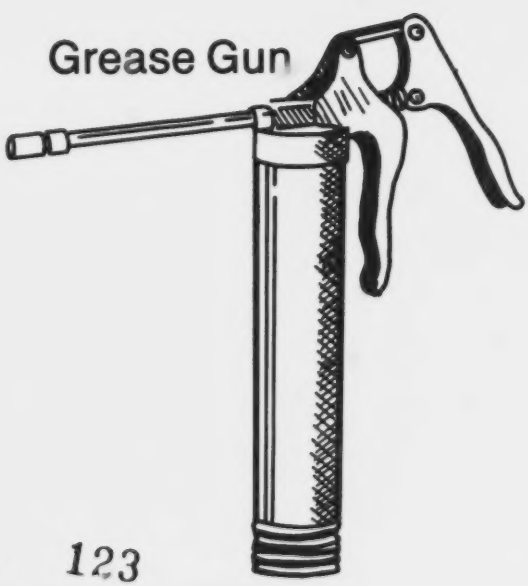


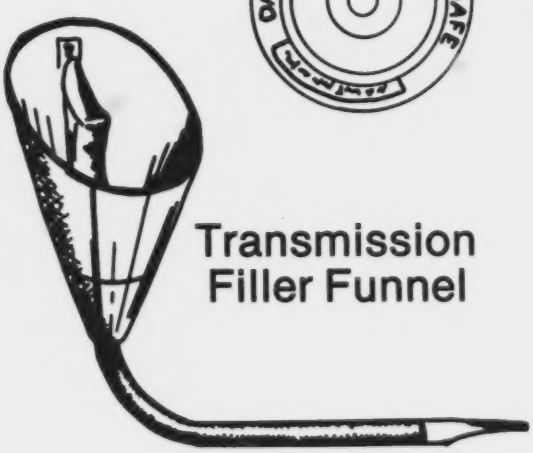
Oil Spout

Oil Can
(Trigger Type)

PCV Tester

Grease Gun

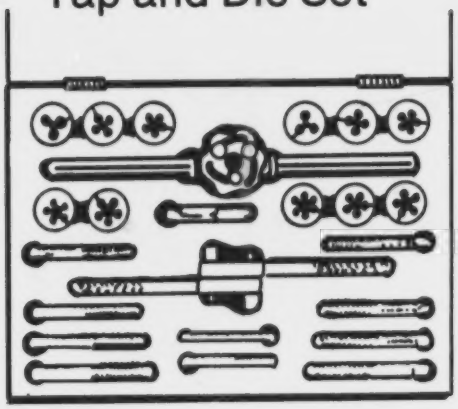




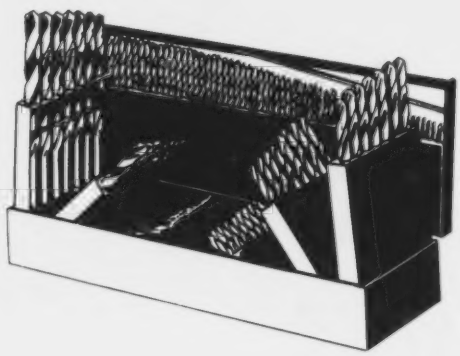
Transmission
Filler Funnel

Miscellaneous Tools

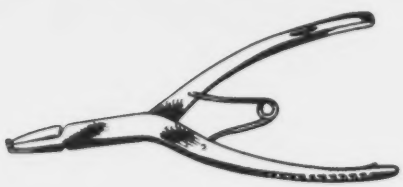
Tap and Die Set



Drills

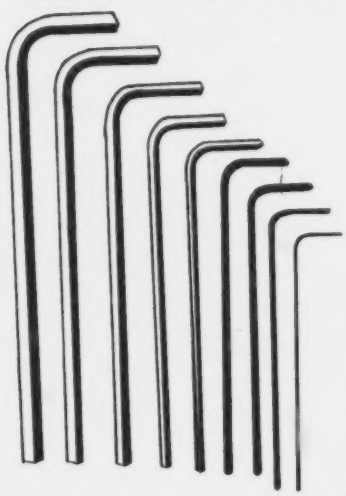


Snap-Ring Pliers

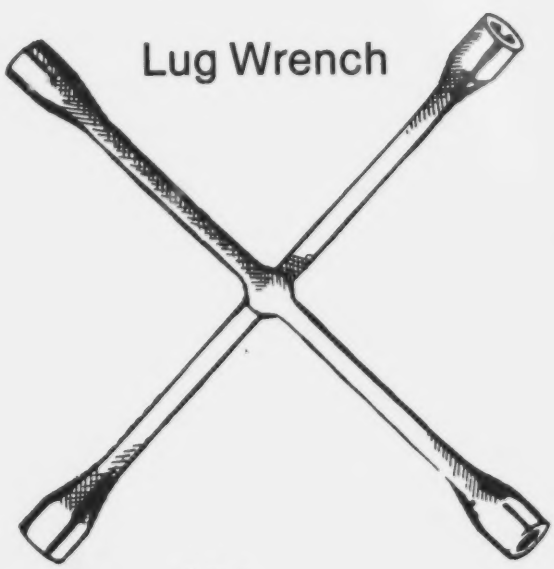


Metal-Cutting Shears

Allen Wrenches

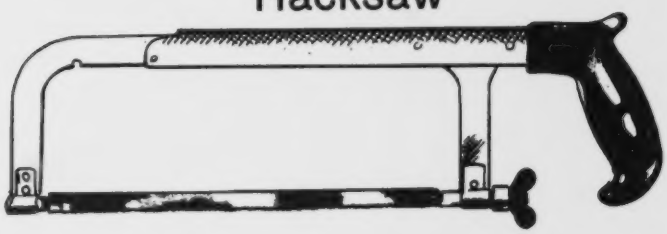


Lug Wrench

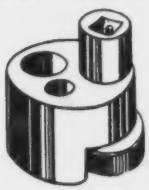


Miscellaneous Tools
(Continued)

Hacksaw

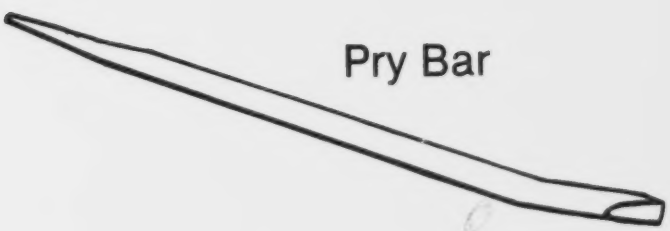


Stud Remover



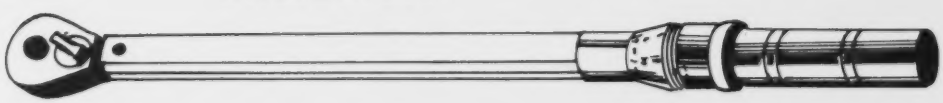
Universal Nut-Cracker

Pry Bar

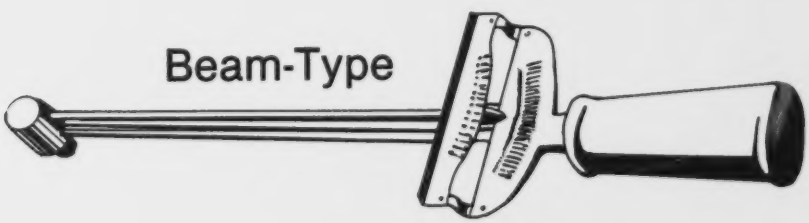


Torque Wrenches

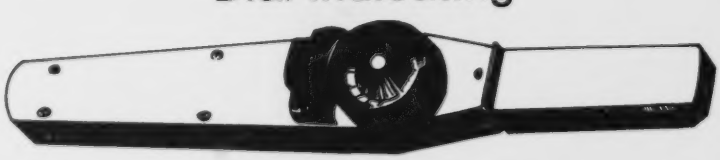
Micrometer



Beam-Type

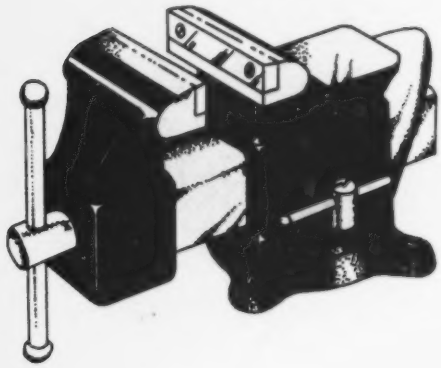


Dial-Indicating



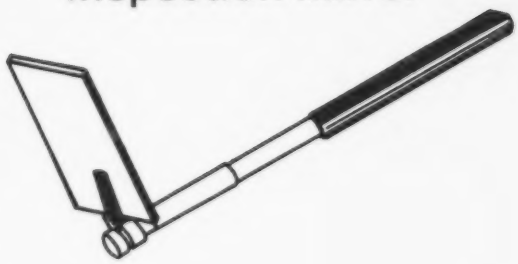
Miscellaneous Tools
(Continued)

Bench Vise

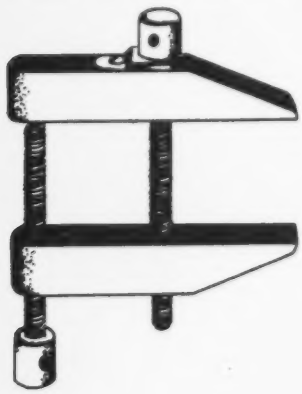


C-Clamp

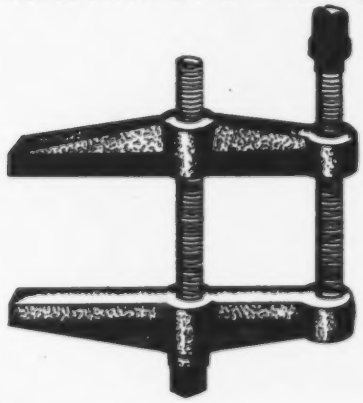
Inspection Mirror



Parallel Clamp

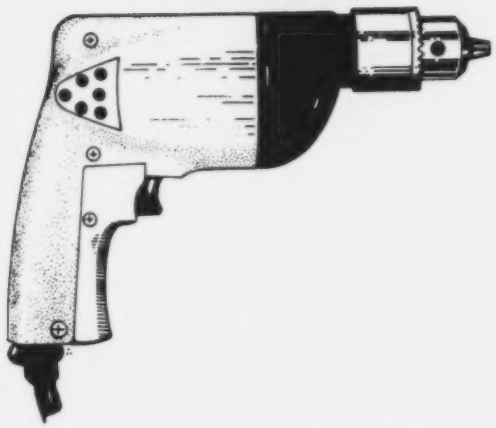


Machinist's Clamp

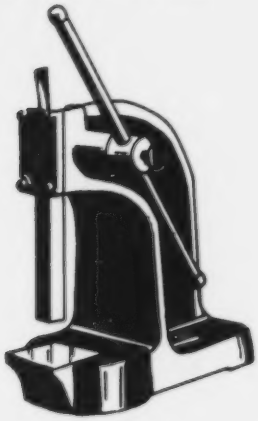


Miscellaneous Tools
(Continued)

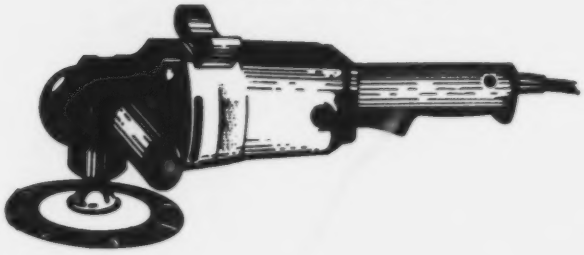
Hand Drill



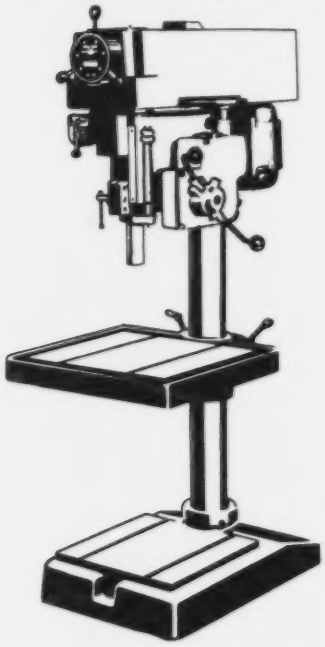
Arbor Press



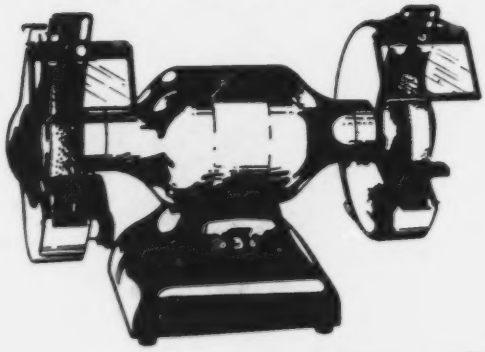
Portable Grinder



Drill Press



Bench Grinder

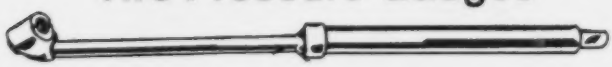


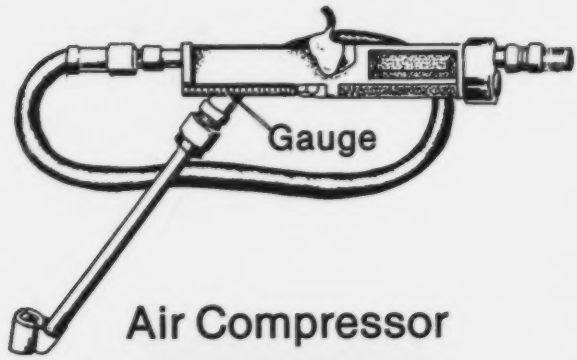
Miscellaneous Tools
(Continued)

Air Nozzle

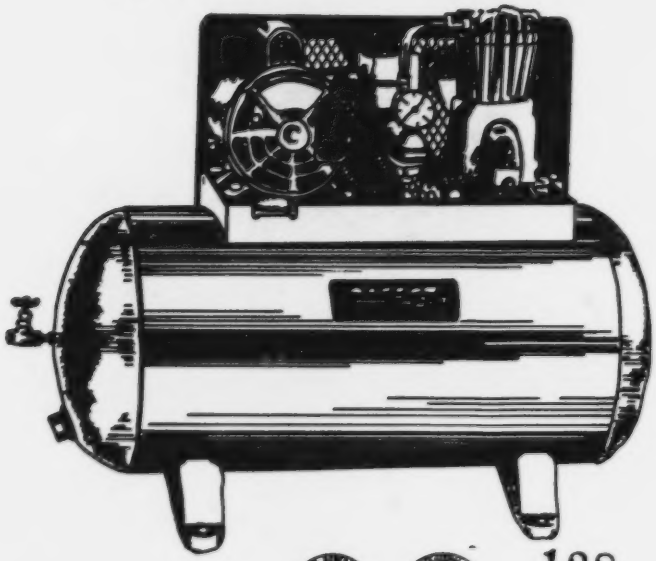
Tire Valve Tool

Tire Pressure Gauges





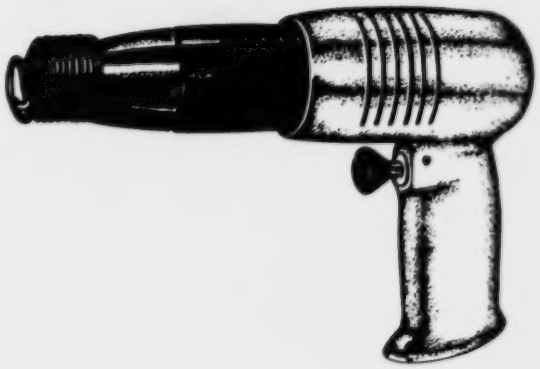
Air Compressor



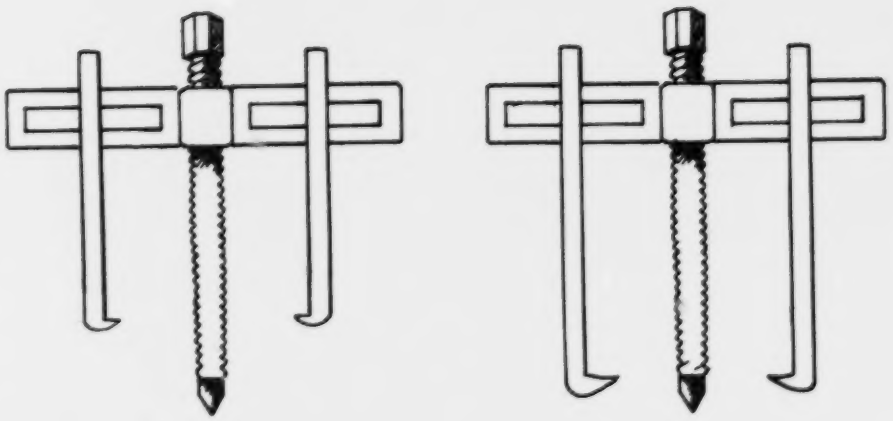
Miscellaneous Tools

Impact Wrench

Impact Hammer



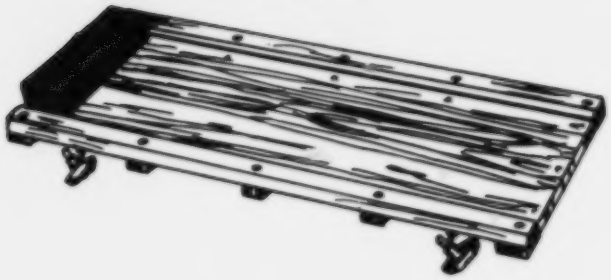
Puller Set
(Bearing, Gear, and Wheel)



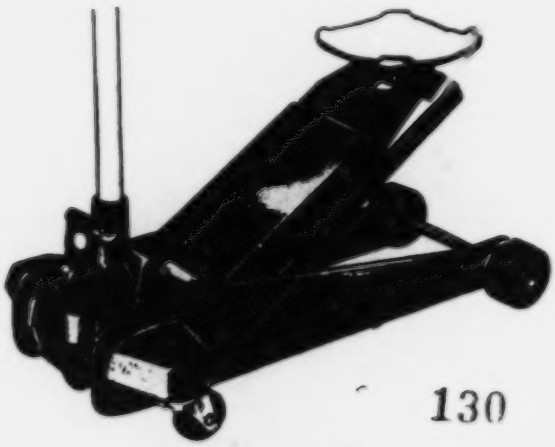
Miscellaneous Tools
(Continued)

Hydraulic Hand Jack

Creeper

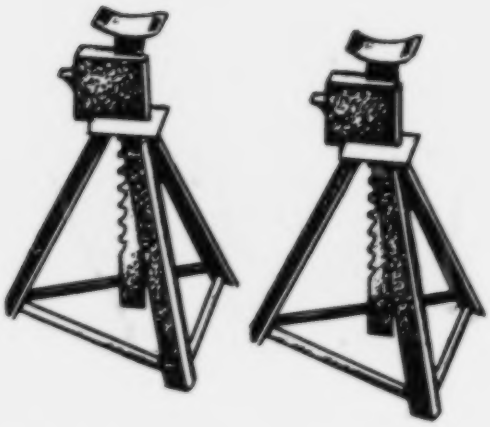


Heavy-Duty Floor Jack



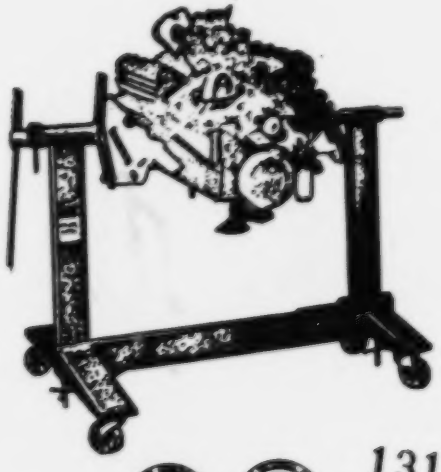
Miscellaneous Tools
(Continued)

Jack Stands



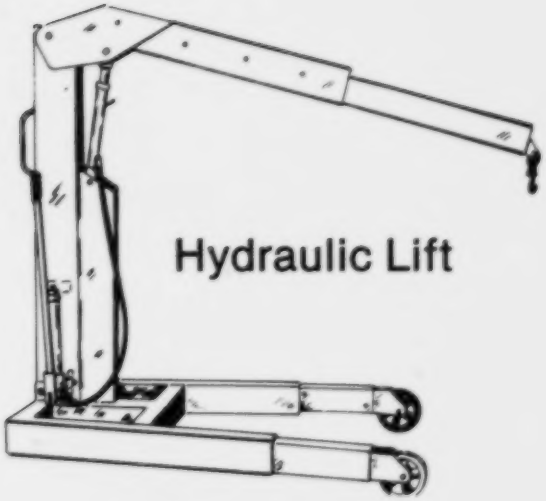
Chain Hoist

Engine Stand



Miscellaneous Tools
(Continued)

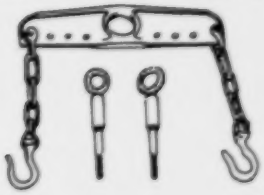
Battery Charger

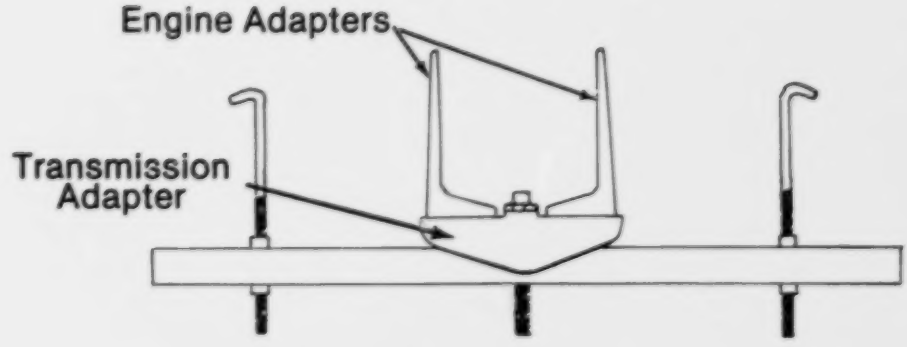


Hydraulic Lift

Engine Lift Adapters

Cylinder-Head Bolt





Engine or Transmission Support

HAND TOOLS AND MISCELLANEOUS TOOLS
UNIT II

JOB SHEET #1 — FIT A SCREWDRIVER

I. Equipment and materials

A. Grinder

B. Screwdriver

C. Screw with head size equal to width of screwdriver blade

D. Container of water

E. Full face shield or goggles

II. Procedure

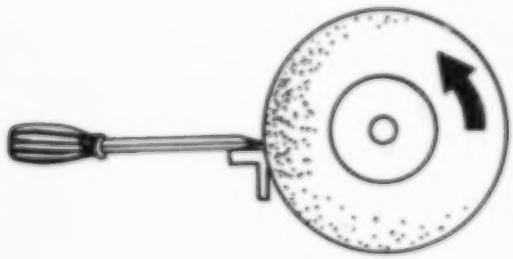
(NOTE: The following safety tips should be strictly enforced.)

**(CAUTION: *Be sure* to use the proper type and size of grinding wheel for the job.
Be sure to operate grinder at the recommended speed.
Be sure that wheel is properly mounted on spindle.
Never stand in front of grinder when starting.
Always wear safety goggles when operating grinder.)**

A. Place screwdriver against the grinder wheel at a 90-degree angle to square the tip (Figure 1)

(CAUTION: Keep tool snug against tool rest and keep a firm grip on tool.)

FIGURE 1



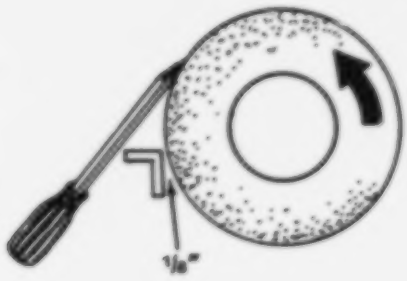
B. Apply light pressure on blade while grinding

JOB SHEET #1

C. Shape both faces of screwdriver (Figure 2)

(CAUTION: Maintain 1/8-inch clearance between grinding wheel and tool rest.)

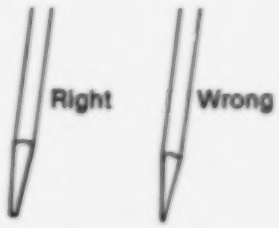
FIGURE 2



D. Use screw head to determine the extent of grinding desired

(NOTE: Do not round or sharpen the end. See Figure 3.)

FIGURE 3



E. Dip point in water frequently to keep point cool

(NOTE: Show fitted screwdriver to your instructor for comments and evaluation.)

F. Clean work area; clean and put away all tools and equipment

HAND TOOLS AND MISCELLANEOUS TOOLS
UNIT II

JOB SHEET #2 — RESHAPE A COLD CHISEL

I. Equipment and materials

A. Cold chisel

B. Grinder

C. Container of water

D. Full face shield or goggles

II. Procedure

(NOTE: The following safety tips should be strictly enforced.)

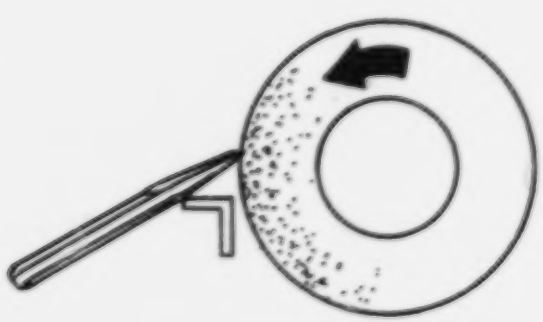
**(CAUTION: *Be sure* to use the proper type and size of grinding wheel for the job.
Be sure to operate grinder at the recommended speed.
Be sure that wheel is properly mounted on spindle.
Never stand in front of grinder when starting.
Always wear safety goggles when operating grinder.)**

A. Reshape point

1. Hold the chisel against the grinder wheel at a 60-degree angle, with handle pointing down (Figure 4)

(CAUTION: Keep tool snug against tool rest and keep a firm grip on tool.)

FIGURE 4



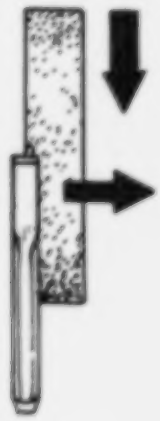
Side View

JOB SHEET #2

2. Move point from side to side across grinding wheel (Figure 5)

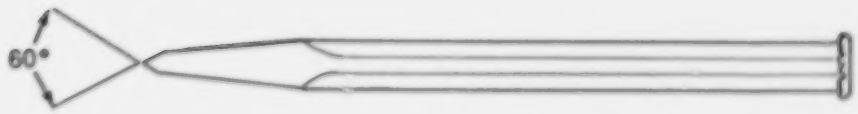
(NOTE: Dip point in water frequently to keep point cool.)

FIGURE 5



3. Grind both sides of the cutting edge in the same manner (Figure 6)

FIGURE 6



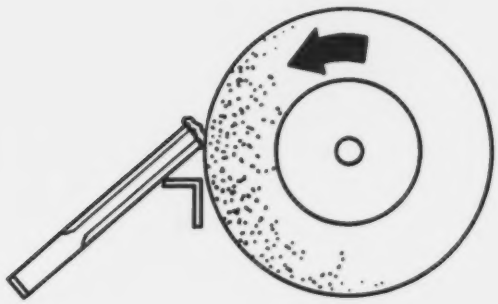
4. Grind the head back into shape if it has become mushroomed

JOB SHEET #2

B. Reshape head

1. Hold chisel firmly against tool guard, with point pointing down (Figure 7)

FIGURE 7



Side View

2. Rotate chisel slowly as the burrs are ground off (Figure 8)

(NOTE: Dip end of chisel in water frequently to keep end cool.)

FIGURE 8

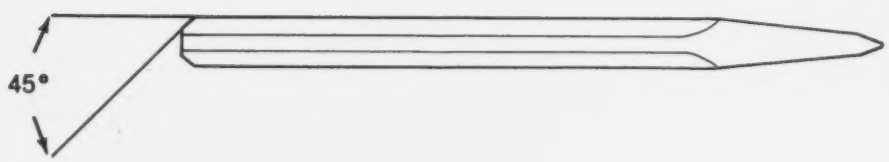
JOB SHEET #2

3. Grind burrs off completely around head of chisel (Figure 9)

FIGURE 9

4. Reshape head of chisel by grinding head at an angle approximately 45 degrees to grinder wheel (Figure 10)

FIGURE 10



(NOTE: Show reshaped chisel to your instructor for comments and evaluation.)

C. Clean work area; clean and put away all tools and equipment

HAND TOOLS AND MISCELLANEOUS TOOLS
UNIT II

JOB SHEET #3 — CUT FLAT METAL WITH A COLD CHISEL

I. Equipment and materials

A. Marker (soapstone or chalk)

B. Flat strip of metal

C. Chisel

D. Hammer

E. Vise

F. Full face shield

II. Procedure

A. Mark the metal

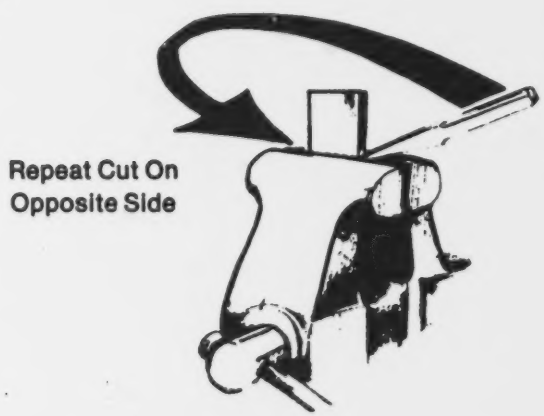
B. Place metal in vise with cutting mark just above jaws of vise

C. Select proper size chisel and hammer

(NOTE: For larger size metal, use a larger chisel and hammer.)

D. Place chisel at side of metal to start the shearing point (Figure 11)

FIGURE 11



JOB SHEET #3

E. Hold chisel at approximately a 60-degree angle to the metal

F. Make cuts from each end of metal to center, and on both sides

(NOTE: Drive the chisel with a hammer.)

G. Bend metal back and forth until it breaks

(NOTE: Show chisel-cut metal to your instructor for comments and evaluation.)

H. Clean work area; clean and put away all tools and equipment

HAND TOOLS AND MISCELLANEOUS TOOLS
UNIT II

JOB SHEET #4 — DRESS A GRINDING WHEEL

I. Equipment and materials

A. Grinding wheel

B. Dressing tool

C. Full face shield

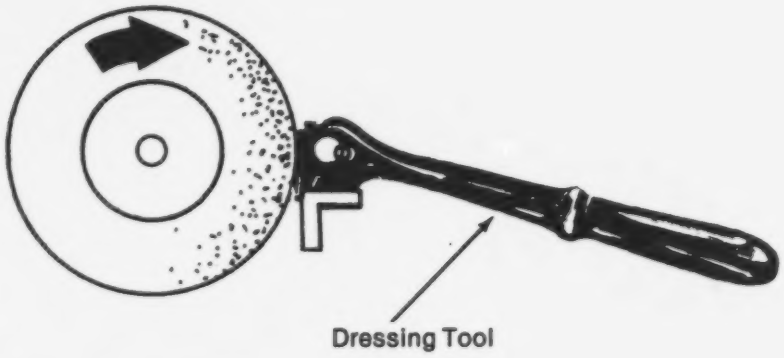
II. Procedure

A. Select the proper dressing tool

B. Set dressing tool on grinder tool rest; press it firmly against wheel (Figure 12)

(NOTE: Use enough pressure on the tool to prevent sparks.)

FIGURE 12



C. Dress grinding wheel with tool until edges are square with sides

(NOTE: Show grinding wheel to your instructor for comments and evaluation.)

D. Clean work area; clean and put away all tools and equipment

HAND TOOLS AND MISCELLANEOUS TOOLS
UNIT II

JOB SHEET #5 — DRAWFILE A FLAT SURFACE

I. Equipment and materials

A. File handle

B. Machinist's file

(NOTE: A machinist's file has double-cut teeth for cutting in both directions.)

C. Vise

D. Cylinder head or stock to be drawfiled

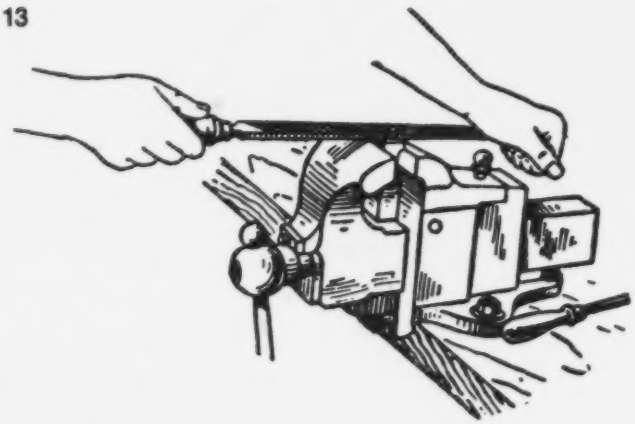
E. Safety glasses

II. Procedure

A. Secure stock

1. Secure cylinder head on suitable stand or fixture (Figure 13)

FIGURE 13



2. Secure smaller stock in vise

B. Equip file with a tight-fitting handle

C. Drawfile (file crosswise) over work with a light pressure

D. Apply enough pressure to keep file cutting in both directions

(NOTE: Show your work to the instructor for comments and evaluation.)

E. Clean work area; clean and put away all tools and equipment

HAND TOOLS AND MISCELLANEOUS TOOLS
UNIT II

JOB SHEET #6 — SHARPEN A TWIST DRILL

I. Equipment and materials

A. Grinder

B. Twist drill

C. Container of water

D. Full face shield

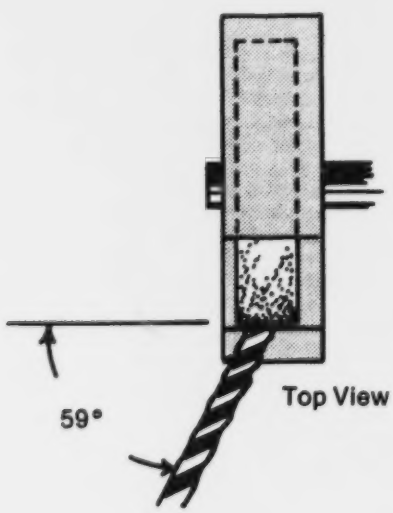
II. Procedure

(NOTE: The following safety tips should be strictly enforced.)

(CAUTION: *Be sure* to use the proper type and size of grinding wheel for the job.
***Be sure* to operate grinder at the recommended speed.**
***Be sure* that wheel is properly mounted on spindle.**
***Never* stand in front of grinder when starting.**
***Always* wear safety goggles when operating grinder.)**

A. Place drill point against grinding wheel at approximately a 59-degree angle (Figure 14)

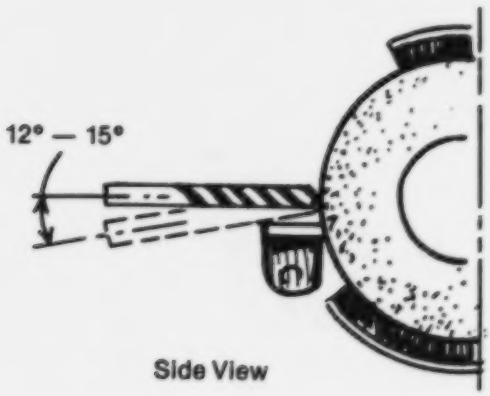
FIGURE 14



JOB SHEET #6

B. Lower shank and raise cutting point of bit against wheel, using both hands (Figure 15)

FIGURE 15



Side View

C. Rotate bit in a clockwise manner while grinding

(NOTE: Dip the point in water frequently to keep point cool.)

D. Grind both lips in the same manner

(NOTE: Show completed work to instructor for comments and evaluation.)

E. Clean work area; clean and put away all tools and equipment

HAND TOOLS AND MISCELLANEOUS TOOLS
UNIT II

JOB SHEET #7 — DRILL HOLES WITH A DRILL PRESS

I. Equipment and materials

A. Small piece of flat metal

B. Drill press

C. Center punch

D. Hammer

E. Wooden block

F. Cutting oil

G. C-clamp

H. Safety goggles

II. Procedure

A. Mark the hole with center punch (Figure 16)

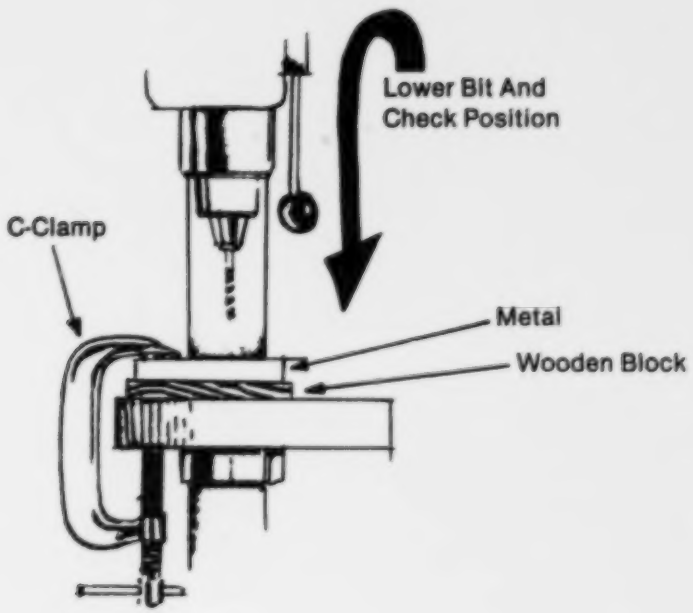
FIGURE 16

B. Place metal on wooden block

JOB SHEET #7

C. Clamp metal securely to prevent it from spinning (Figure 17)

FIGURE 17



D. Feed bit down to metal

E. Raise bit slightly to see if you are drilling in the proper place

(NOTE: The piece of metal may need to be adjusted.)

F. Lower bit and start drilling

G. Continue drilling, using cutting oil on drill bit 2 or 3 inches above the work

(NOTE: Show completed work to instructor for comments and evaluation.)

H. Clean work area; clean and put away all tools and equipment

HAND TOOLS AND MISCELLANEOUS TOOLS
UNIT II

JOB SHEET #8 — DRAW A TWIST DRILL HOLE TO CORRECT CENTER

I. Equipment and materials

A. Electric drill with ½-inch chuck

B. High-speed twist drill

C. Center punch and chisel

D. Ball-peen hammer

E. Stock to be drilled

F. Lubricating oil

II. Procedure

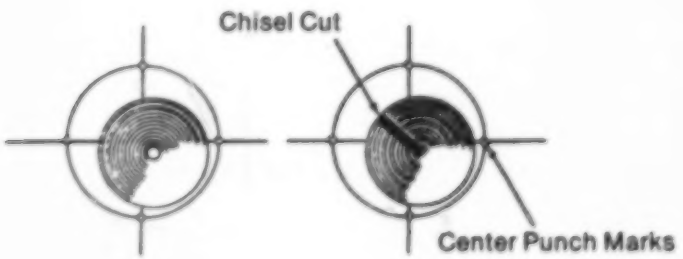
(NOTE: This procedure may be used when an incorrect center punch hole has been made.)

A. Make a center punch mark on stock

B. Enlarge center punch mark slightly, but remove center punch before entire point has entered material

C. Make a chisel cut from center punch mark to side toward which drill should be drawn (Figure 18)

FIGURE 18



How to Draw the Drill Back to Correct Center

JOB SHEET #8

D. Make another punch mark for new center

E. Repeat step B

(NOTE: Show completed work to instructor for comments and evaluation.)

F. Clean work area; clean and put away all tools and equipment

HAND TOOLS AND MISCELLANEOUS TOOLS
UNIT II

JOB SHEET #9 — CHECK TORQUE WRENCH FOR ACCURACY

I. Equipment and materials

A. Torque wrench

B. Vise

C. Known weight

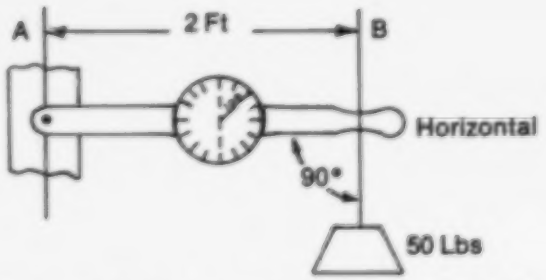
(NOTE: Weight should be at least one-third the capacity of the torque wrench.)

D. Strong cord

II. Procedure

A. Hang torque wrench on a fixed nut or secure in vise (Figure 19)

FIGURE 19



A = Center Line of Nut B = Point of Suspension

B. Set torque indicator at zero

C. Hang known weight from wrench handle at any known distance from center of nut (Figure 19)

D. Multiply weight times the distance from A to B (Figure 19)

E. Compare answer to indicator reading

(NOTE: In the example in Figure 19, 50 pounds × 2 feet = 100 foot-pounds.)

F. Clean work area; clean and put away all tools and equipment

HAND TOOLS AND MISCELLANEOUS TOOLS
UNIT II

JOB SHEET #10 — REPLACE A HAMMER HANDLE

I. Equipment and materials

A. Hammer with a broken handle

B. Hacksaw

C. Twist drill

D. Punch

E. Rasp

F. Handsaw

G. Soft-faced hammer

H. Vise and vise jaw covers

(NOTE: Cover vise jaws with sheet metal or use wooden blocks to prevent damage to the hammer and handle.)

I. New handle

J. Metal or wooden wedge

K. Safety glasses

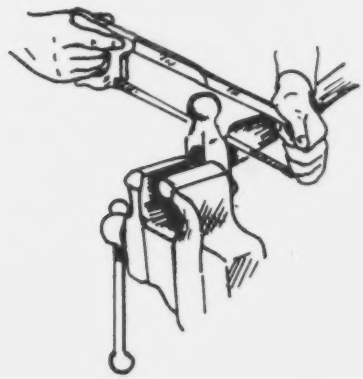
JOB SHEET #10

II. Procedure

A. Place hammer head in vise

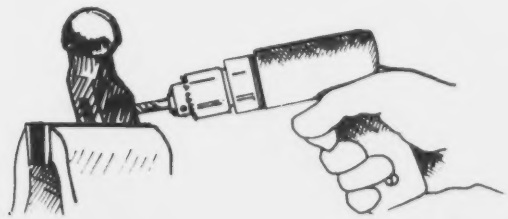
B. Saw broken handle close to hammer head with hacksaw (Figure 20)

FIGURE 20



C. Remove wood from hammer eye by first drilling with twist drill and then punching out remainder of wood (Figure 21)

FIGURE 21

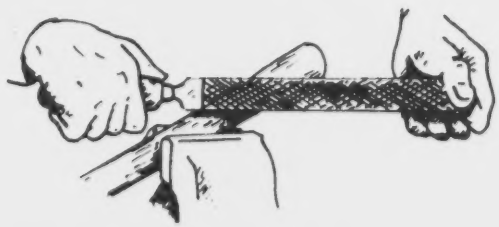


D. Place new handle in vise

E. Work new handle down to size with a rasp (Figure 22)

(NOTE: Try handle in hammer head frequently.)

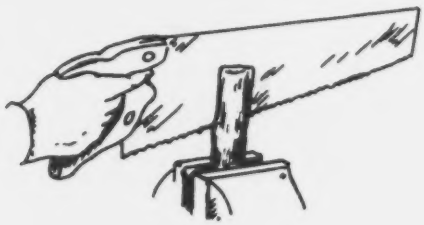
FIGURE 22



JOB SHEET #10

F. Use handsaw to make a cut (split) across diameter of top of handle to a distance of about two-thirds the depth of hammer eye (Figure 23)

FIGURE 23



G. Drive handle firmly into place, using a soft-faced hammer (Figure 24)

FIGURE 24

H. Drive wedge tightly into cut in end of handle

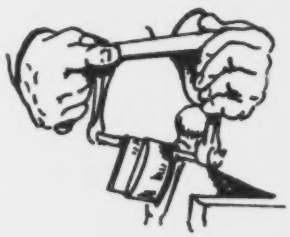
I. Place hammer in vise

JOB SHEET #10

J. Use hacksaw to cut off length of handle and wedge that extends through top of hammer head (Figure 25)

(NOTE: If steel wedges are used, the end of the handle need not be cut across the diameter because the wedge can be driven into place after the handle has been cut off even with the head.)

FIGURE 25



(NOTE: Show completed work to instructor for comments and evaluation.)

K. Clean work area; clean and put away all tools and equipment

HAND TOOLS AND MISCELLANEOUS TOOLS
UNIT II

TEST

NAME _____ SCORE _____

1. State the purpose of tools.

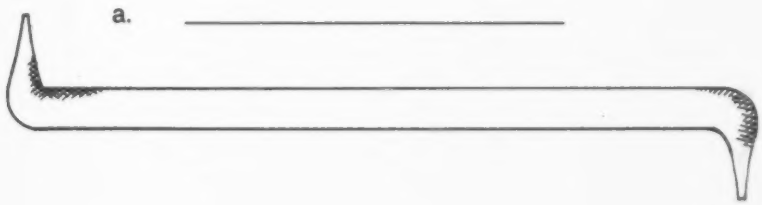
_____

_____

2. Identify the following types of screwdrivers. Write the correct names in the blanks.

Standard or common **Clutch** **Offset**
Phillips **Reed and Prince**

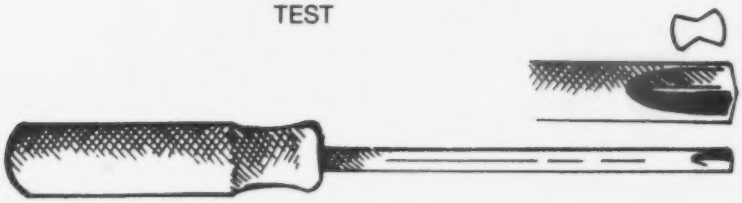
a. _____



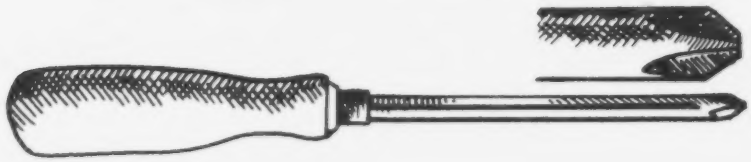
b. _____

c. _____

TEST



d. _____



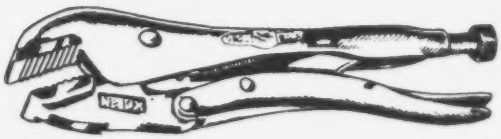
e. _____

3. Identify the following types of pliers. Write the correct names in the blanks.

Diagonal side cutter **Needlenose** **Slip-joint**
Channel lock **Lock grip**

a. _____

b. _____



c. _____

d. _____

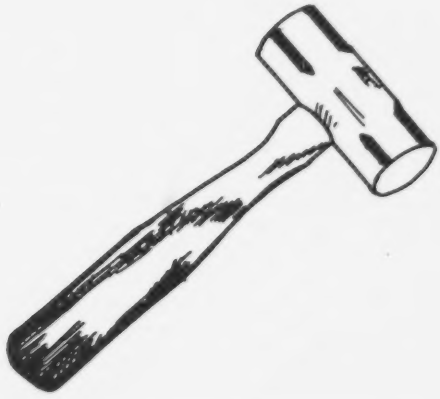
e. _____

TEST

4. Identify the following types of hammers. Write the correct names in the blanks.

Ball-peen **Sledgehammer** **Brass**
Rubber **Plastic tip**

a. _____



b. _____

c. _____

d. _____

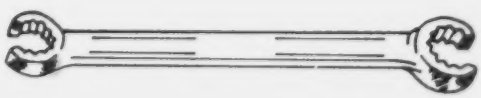
TEST

e. _____

5. Identify the following types of wrenches. Write the correct names in the blanks.

Obstruction box end	**Adjustable**	**Combination**
Open end	**Box end**	**Flex head**
Tubing	**Pipe**	

a. _____



b. _____

c. _____

d. _____

e. _____

f. _____

g. _____

h. _____

TEST

6. Label the following components of a socket set. Write the correct names in the blanks.

a. _____

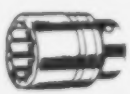
b. _____

c. _____

d. _____

e. _____

f. _____



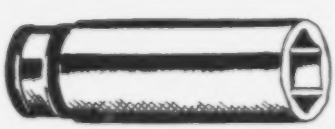
g. _____

7. Identify the following types of sockets. Write the correct names in the blanks.

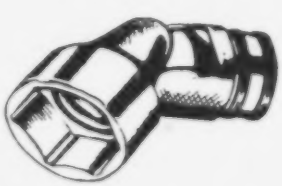
Six point
Standard

Twelve point
Universal

Deep well



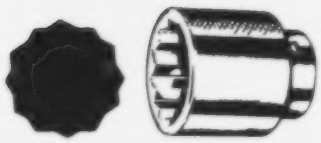
a. _____

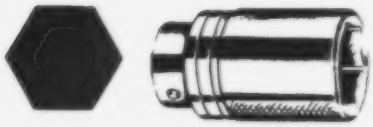


b. _____

c. _____

TEST



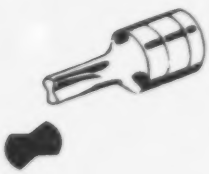


d. _____ e. _____

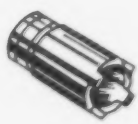
8. Identify the following types of special-purpose sockets. Write the correct names in the blanks.

Standard	**Phillips**	**Clutch**
Drag link	**Triple-square cap**	**Allen or hex head**
Shock absorber	**Prong nut or dash nut**	**Oil sender**
Crowfoot		

a. _____ b. _____ c. _____



d. _____ e. _____ f. _____



g. _____ h. _____ i. _____

TEST

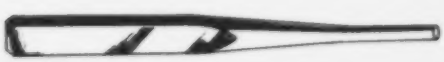
j. _____

9. Identify the following types of punches. Write the correct names in the blanks.

Lining-up
Starting

Drift
Pin

Center



a. _____

b. _____

c. _____

d. _____

e. _____

10. Identify the following types of chisels. Write the correct names in the blanks.

Diamond-point
Cold

Roundnose
Cape

a. _____

b. _____

c. _____

d. _____

TEST

11. Label the following types of files. Write the correct names in the blanks.

a. _____

b. _____

c. _____

d. _____

e. _____

f. _____

g. _____

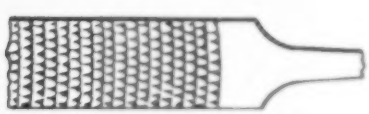
h. _____

12. Identify the following types of file teeth. Write the correct names in the blanks.

Rasp-cut **Double-cut**
Single-cut **Curved**

a. _____

b. _____



c. _____

d. _____

TEST

13. Label the following types of parts-cleaning tools. Write the correct names in the blanks.

a. _____ b. _____

c. _____ d. _____

14. Label the following tools used to service batteries. Write the correct names in the blanks.

a. _____ b. _____

c. _____ d. _____

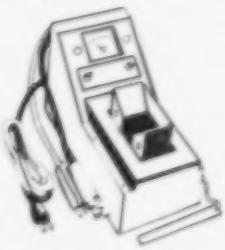
TEST

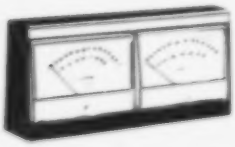
f. _____

e. _____ g. _____

15. Label the following tools used to service the starter system. Write the correct names in the blanks.

a. _____ b. _____

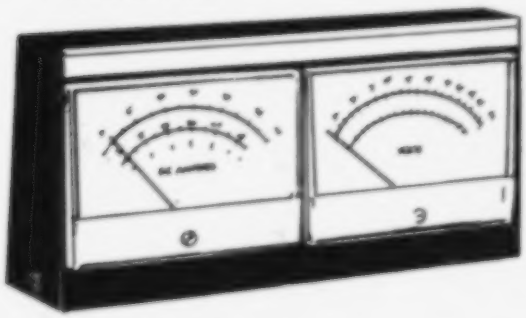




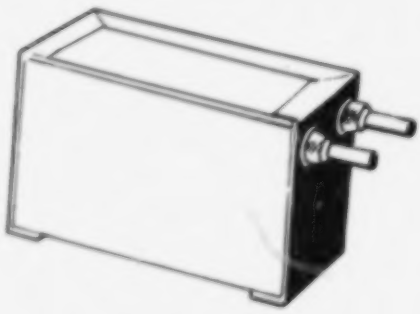
c. _____ d. _____

TEST

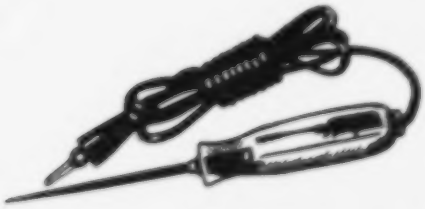
16. Label the following tools used to service the charging system. Write the correct names in the blanks.



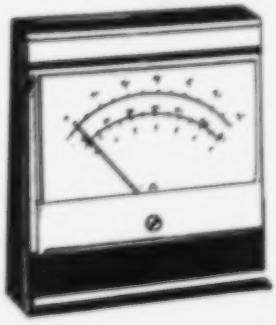
a. _____



b. _____



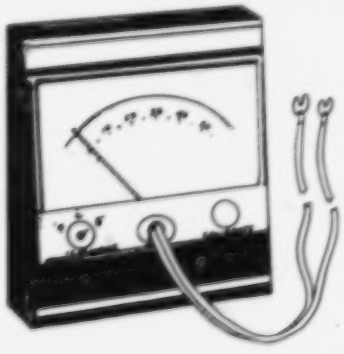
c. _____



d. _____

17. Label the following tools used to service the ignition system. Write the correct names in the blanks.

a. _____

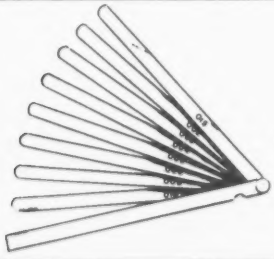


b. _____

TEST

c. _____

d. _____



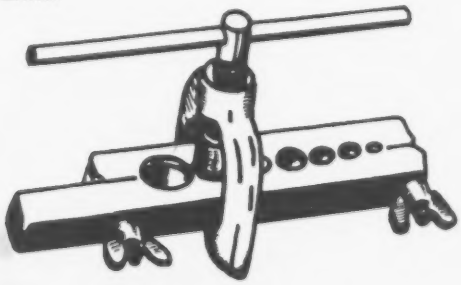
e. _____

f. _____

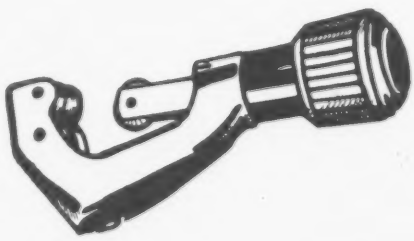
g. _____

h. _____

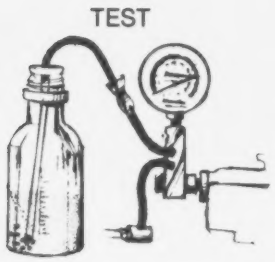
18. Label the following tools used to service the fuel system. Write the correct names in the blanks.



a. _____

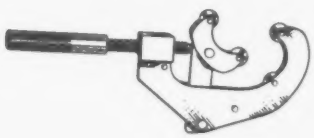


b. _____

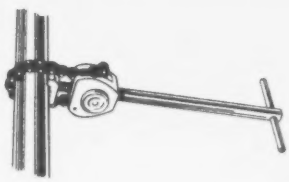


c. _____

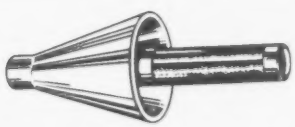
19. Label the following tools used to service the exhaust system. Write the correct names in the blanks.



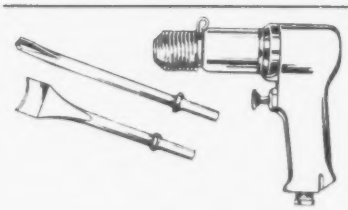
a. _____



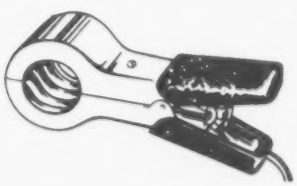
b. _____



c. _____



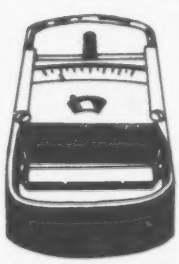
d. _____



e. _____

f. _____

20. Label the following tools used to service the cooling system. Write the correct names in the blanks.



a. _____ _____

TEST

c. _____

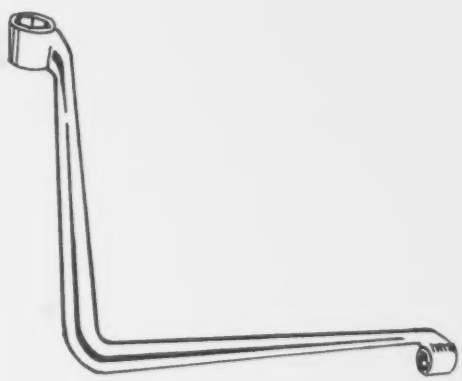
d. _____

e. _____

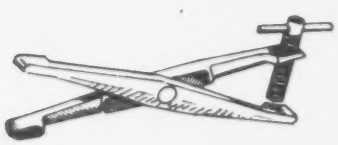
f. _____

21. Label the following tools used to service the brake system. Write the correct names in the blanks.

a. _____



b. _____

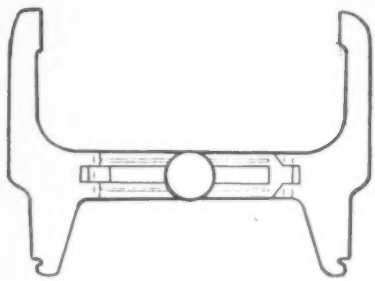


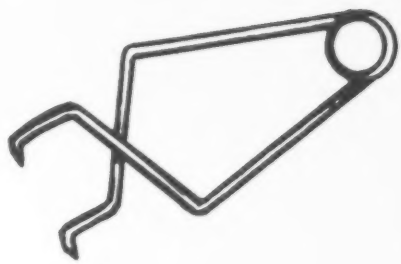
c. _____

d. _____

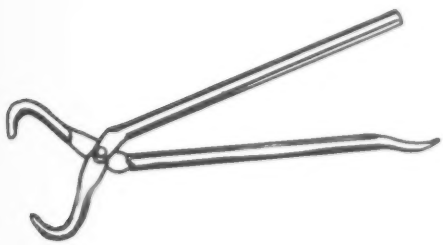
TEST

e. _____



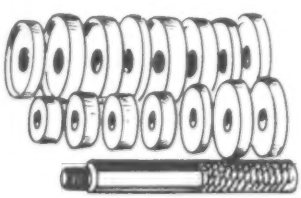


f. _____ g. _____



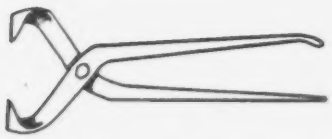
h. _____ i. _____

22. Label the following tools used to service the front-end system. Write the correct names in the blanks.



a. _____ b. _____

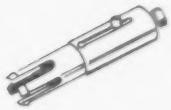
TEST



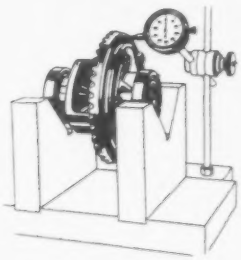
c. _____ d. _____

e. _____

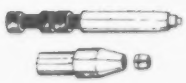
23. Label the following tools used to service the drive line. Write the correct names in the blanks.

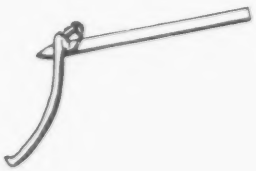


a. _____ b. _____ c. _____



d. _____ e. _____ f. _____





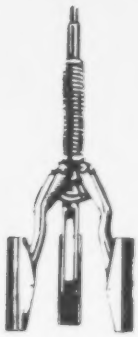
g. _____ h. _____ i. _____

TEST

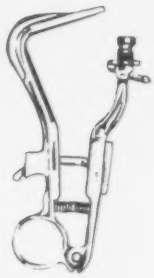
24. Identify the following tools used in engine repair. Write the correct names in the blanks.

Cylinder taper gauge
Ridge reamer
Piston ring compressor
Piston ring groove cleaner
Cylinder deglazing hone
Valve spring compressor
Valve spring pressure tester
Piston ring expander

a. _____

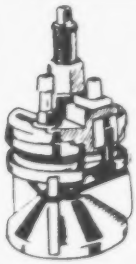


b. _____



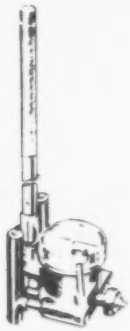
c. _____

d. _____

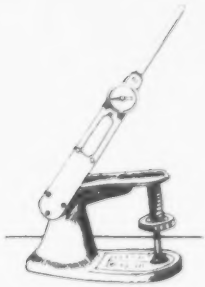


e. _____

f. _____



g. _____



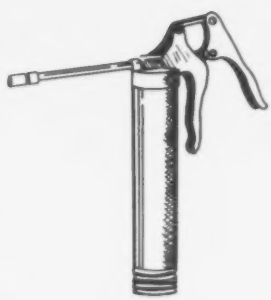
h. _____

TEST

25. Identify the following tools used in lubrication service. Write the correct names in the blanks.

Transmission filler funnel
Oil filter removing tools
Grease gun
Grease-fitting tool
Oil can (trigger type)
Oil spout
PCV tester

a. _____ b. _____



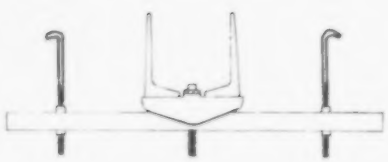
c. _____ d. _____ e. _____

f. _____ g. _____

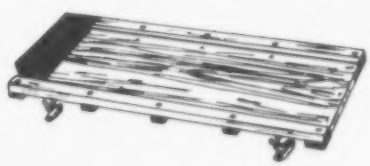
TEST

26. Identify the following miscellaneous and special tools and equipment. Write the correct names in the blanks.

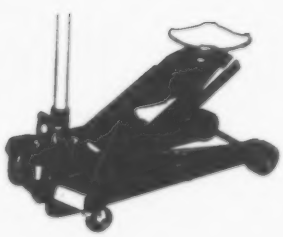
Tap and die set	Stud remover	Hacksaw
Metal-cutting shears	Pry bar	Snap-ring pliers
Universal nut-cracker	C-clamp	Bench vise
Torque wrenches	Drill press	Parallel clamp
Inspection mirror	Hand drill	Portable grinder
Machinist's clamp	Air compressor	Arbor press
Bench grinder	Puller set (bearing, gear, and wheel)	Tire pressure gauges
Tire valve tool	Creeper	Impact wrench
Impact hammer	Jack stands	Hydraulic hand jack
Heavy-duty floor jack	Chain hoist	Engine lift adapter (cylinder-head bolt)
Engine stand	Engine lift adapters (engine or transmission support)	Hydraulic lift
Battery charger	Allen wrenches	Air nozzle
Drills		
Lug wrench		



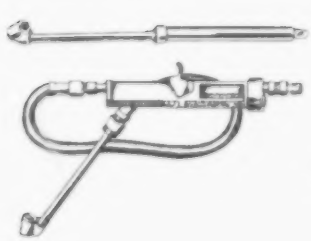
a. _____



b. _____

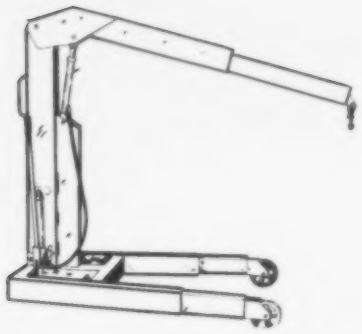


c. _____

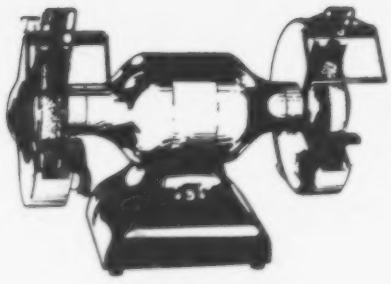


d. _____

TEST

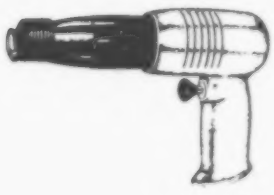


e. _____



f. _____

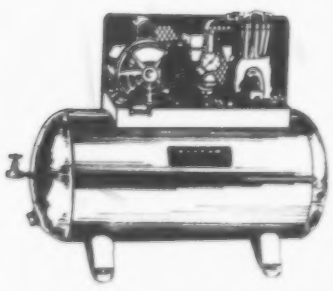
g. _____



h. _____

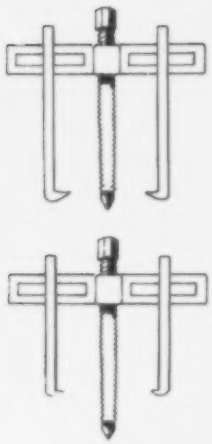
i. _____

j. _____

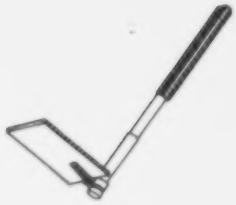


k. _____

TEST



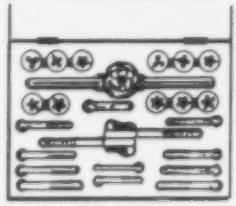
l. _____



m. _____

n. _____

o. _____

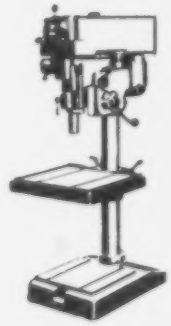


p. _____

q. _____

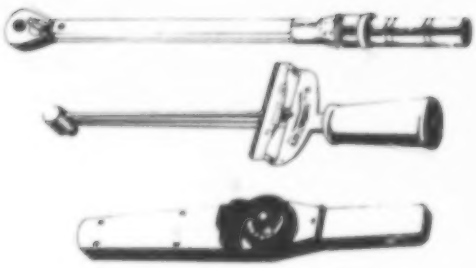
r. _____

s. _____



t. _____

TEST

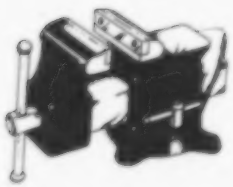


u. _____ v. _____

w. _____ x. _____

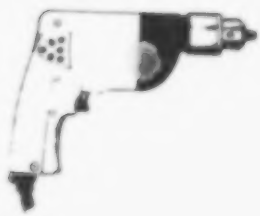
y. _____ z. _____

TEST



aa. _____

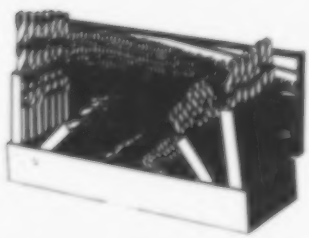
bb. _____



cc. _____

dd. _____

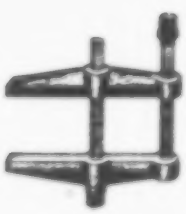
ee. _____



ff. _____

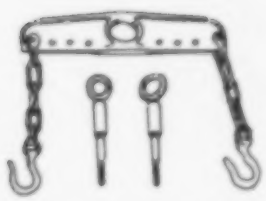
gg. _____

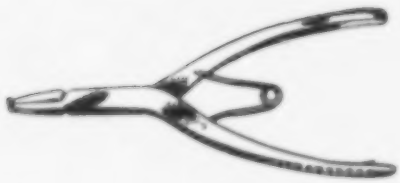
hh. _____



ii. _____

TEST





jj. _____ kk. _____

ll. _____

(NOTE: Test question 27 lists the job sheets. They are an important part of this test. If they have not been completed, check with your instructor.)

27. Demonstrate the ability to

a. Fit a screwdriver.

b. Reshape a cold chisel.

c. Cut flat metal with a cold chisel.

d. Dress a grinding wheel.

e. Drawfile a flat surface.

f. Sharpen a twist drill.

g. Drill holes with a drill press.

h. Draw a twist drill hole to correct center.

i. Check torque wrench for accuracy.

j. Replace a hammer handle.

HAND TOOLS AND MISCELLANEOUS TOOLS
UNIT II

ANSWERS TO TEST

1. To allow the mechanic to perform a variety of service procedures quickly, safely, and efficiently

2. a. Reed and Prince
   b. Offset
   c. Standard or common
   d. Clutch
   e. Phillips

3. a. Channel lock
   b. Diagonal side cutter
   c. Lock grip
   d. Needlenose
   e. Slip-joint

4. a. Rubber
   b. Sledgehammer
   c. Plastic tip
   d. Ball-peen
   e. Brass

5. a. Adjustable
   b. Tubing
   c. Combination
   d. Pipe
   e. Box end
   f. Open end
   g. Obstruction box end
   h. Flex head

6. a. Break-over handle
   b. Extension
   c. Ratchet handle
   d. Universal joint
   e. Speed handle
   f. Sliding T-handle
   g. Socket

ANSWERS TO TEST

7. a. Deep well
   b. Universal
   c. Standard
   d. Twelve point
   e. Six point

8. a. Crowfoot
   b. Triple-square cap
   c. Oil sender
   d. Clutch
   e. Shock absorber
   f. Phillips
   g. Drag link
   h. Standard
   i. Prong nut or dash nut
   j. Allen or hex head

9. a. Pin
   b. Starting
   c. Drift
   d. Center
   e. Lining-up

10. a. Roundnose
    b. Cape
    c. Diamond-point
    d. Cold

11. a. Slitting
    b. Square
    c. Half round
    d. Cant saw
    e. Flat
    f. Knife
    g. Round
    h. Triangular (three-square)

12. a. Single-cut
    b. Double-cut
    c. Rasp-cut
    d. Curved

ANSWERS TO TEST

13. a. Gasket scraper
    b. Parts-cleaning brush
    c. Carbon scraper
    d. Wire brush

14. a. Cable spreader
    b. Terminal pliers
    c. Hydrometer
    d. Cable puller
    e. Battery filler
    f. Post and cable cleaner
    g. Lifting strap

15. a. Remote-control starter switch
    b. Bushing driver set
    c. Growler
    d. Amp-volt tester

16. a. Amp-volt tester
    b. Diode tester
    c. Continuity light
    d. Ohmmeter

17. a. Timing light
    b. Dwell meter
    c. Insulated pliers
    d. Spark plug gauge
    e. Feeler gauge
    f. Spark plug ratchet and socket
    g. Distributor wrench
    h. Spring gauge

18. a. Flaring tool
    b. Tubing cutter
    c. Fuel-pump tester

ANSWERS TO TEST

19. a. Hand pipe cutter
    b. Chain wrench
    c. Straightening cone
    d. Power chisel
    e. Electric pipe-joint heater
    f. Pipe-expanding tool

20. a. Belt-tension gauge
    b. Radiator pressure tester
    c. Hose-clamp pliers
    d. Antifreeze tester
    e. Fan wrench
    f. Radiator hose remover

21. a. Cylinder hone
    b. Bleeder wrench
    c. Disc brake pad spreader
    d. Spring pliers
    e. Adjusting tool
    f. Brake shoe adjusting gauge
    g. Cylinder clamp
    h. Grease cap remover
    i. Bleeder tube

22. a. Seal driver set
    b. Ball-joint remover
    c. Tie-rod-end remover
    d. Dust cover remover
    e. Toe-in adjusting wrench

23. a. Universal-joint press set
    b. Transmission bushing driver
    c. Transmission bushing puller
    d. Snap-ring pliers
    e. Dial indicator
    f. Differential adjusting tool
    g. Automatic transmission pressure gauge set
    h. Clutch aligning set
    i. Flywheel turner

24. a. Valve spring compressor
    b. Cylinder deglazing hone
    c. Piston ring groove cleaner
    d. Piston ring expander
    e. Ridge reamer
    f. Piston ring compressor
    g. Cylinder taper gauge
    h. Valve spring pressure tester

ANSWERS TO TEST

25.
a. Oil filter removing tools
b. Transmission filler funnel
c. PCV tester
d. Grease gun
e. Oil can (trigger type)
f. Grease-fitting tool
g. Oil spout

26.
a. Engine lift adapter (engine or transmission support)
b. Creeper
c. Heavy-duty floor jack
d. Tire pressure gauges
e. Hydraulic lift
f. Bench grinder
g. C-clamp
h. Impact hammer
i. Air nozzle
j. Jack stands
k. Air compressor
l. Puller set (bearing, gear, and wheel)
m. Inspection mirror
n. Parallel clamp
o. Universal nut-cracker
p. Tap and die set
q. Tire valve tool
r. Chain hoist
s. Lug wrench
t. Drill press
u. Stud remover
v. Torque wrenches
w. Portable grinder
x. Metal-cutting shears
y. Pry bar
z. Hacksaw
aa. Bench vise
bb. Hydraulic hand jack
cc. Hand drill
dd. Allen wrenches
ee. Impact wrench
ff. Drills
gg. Battery charger
hh. Arbor press
ii. Machinist's clamp
jj. Engine lift adapter (cylinder-head bolt)
kk. Snap-ring pliers
ll. Engine stand

27. Performance skills evaluated to the satisfaction of the instructor

MEASURING
UNIT III

UNIT OBJECTIVE

After completing this unit, the student should be able to identify and use measuring tools and their parts. The student will show this knowledge by completing assignment sheets, job sheets, and unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match terms associated with measuring to their correct definitions.
2. Identify types of measuring tools used in shop work.
3. State guidelines for using rules.
4. List steps for reading the rule.
5. Read a rule to the nearest 1/32 of an inch.
6. Label the parts of a combination set.
7. Match parts of a combination set to their correct uses.
8. Identify types of calipers.
9. Describe uses of types of calipers.
10. Identify parts of a vernier caliper.
11. Select from a list uses of a vernier caliper.
12. Label the parts of an outside micrometer caliper.
13. Read micrometer calipers.
14. Label the parts of an inside micrometer caliper.
15. Select from a list uses of an inside micrometer caliper.
16. List rules for use and care of precision instruments.
17. Demonstrate the ability to
    a. Check and adjust micrometer for accuracy.
    b. Adjust micrometer to eliminate play in spindle.

MEASURING
UNIT III

SUGGESTED ACTIVITIES

I. Suggested activities

A. Obtain transparencies.

(NOTE: Transparencies are available from AGC and CIMC.)

B. Provide students with objective sheet.

C. Discuss unit and specific objectives.

D. Provide students with information, assignment, and job sheets.

E. Discuss information and assignment sheets.

F. Demonstrate and discuss procedures outlined in job sheets.

G. Have students practice using measuring tools.

H. Use transparency and translucent rule when working assignment sheets.

I. Give test.

J. Complete appropriate section of competency profiles.

(NOTE: Competency profiles are available from AGC and CIMC.)

II. Instructional materials

A. Objective sheet

B. Suggested activities

C. Information sheet

D. Transparency masters

1. TM #1 — Measuring Tools
2. TM #2 — Measuring Tools (Continued)
3. TM #3 — Measuring Tools (Continued)
4. TM #4 — Graduations on a Rule
5. TM #5 — Reading the Eighths Rule

SUGGESTED ACTIVITIES

6. TM #6 — Reading the Sixteenths Rule
7. TM #7 — Uses of the Inside Micrometer Caliper
8. TM #8 — Uses of the Inside Micrometer Caliper (Continued)
9. TM #9 — Checking the Micrometer for Accuracy

E. Assignment sheets

1. Assignment Sheet #1 — Read a Rule
2. Assignment Sheet #2 — Draw Lines to Specific Lengths
3. Assignment Sheet #3 — Measure Lines
4. Assignment Sheet #4 — Read an Outside Micrometer Caliper
5. Assignment Sheet #5 — Read an Inside Micrometer Caliper

F. Answers to assignment sheets

G. Job sheets

1. Job Sheet #1 — Check and Adjust Micrometer for Accuracy
2. Job Sheet #2 — Adjust Micrometer to Eliminate Play in Spindle

H. Test

I. Answers to test

III. Unit references

A. Armstrong, Ivan J. *Auto Mechanics*, Vol. I. Stillwater, Oklahoma: State Department of Vocational and Technical Education/Curriculum and Instructional Materials Center, 1976.

B. Hendrix, Laborn J. "Bud." *Millwright Instructional Materials.* Stillwater, Oklahoma: State Department of Vocational and Technical Education/Curriculum and Instructional Materials Center and The Associated General Contractors of America,1980.

MEASURING
UNIT III

INFORMATION SHEET

I. Terms and definitions

A. Measuring — Checking predetermined dimensions

B. Inch — Smallest whole unit of linear measure commonly used

C. Foot — Unit of measure consisting of twelve equal parts or inches

D. Fraction — One or more parts of a whole

EXAMPLES: 1/2, 1/4, 3/8, 5/16, 3/32, 7/64

E. Rule — Measuring instrument graduated in whole units and fractions of units

F. Caliper — Measuring instrument that can be adjusted to determine thickness, diameter, and distance between surfaces

G. Dimension — Number of full units and fractions of units between two points

H. Mic — Abbreviation for *micrometer*

I. Dial indicator — Watchlike tool used to show dimensional changes between two parts; accurate to one-thousandth of an inch

J. Vernier — Short scale made to slide along divisions of a graduated instrument to indicate parts of divisions

II. Types of measuring tools used in shop work (Transparencies #1-#3)

A. Steel rule

B. Narrow flexible rule

C. Hook rule

D. Short rule with holder

E. Vernier caliper rule

F. Steel tape

G. Combination set

INFORMATION SHEET

H. Combination depth and angle gauge

I. Caliper

J. Outside micrometer caliper

K. Inside micrometer caliper

L. Dial indicator set

M. Feeler gauge

N. Taper gauge

O. Screw pitch gauge

III. Guidelines for using rules

A. Use proper length and graduation

B. Use finest graduation for accuracy

C. Use a good quality rule

D. Never bend or distort a rule

E. Use 1-inch graduation as reference for accuracy

F. Use rule on edge for better reading

G. Use rule along axis, parallel to plane of measurement

IV. Steps for reading the rule

A. Select scale of required units

B. Total number of graduations

C. Count whole units

D. Reduce graduations to lowest terms

V. Reading a rule (Transparencies #4-#6; Assignment Sheets #1-#3)

A. All types of rules read similarly

(NOTE: Some rules are graduated with more divisions per inch than others.)

INFORMATION SHEET

B. Procedure for reading different types of rules

1. Determine number of graduations per inch

   a. Locate small figures at zero end of rule that designate divisions per inch

   b. Count divisions in 1 inch

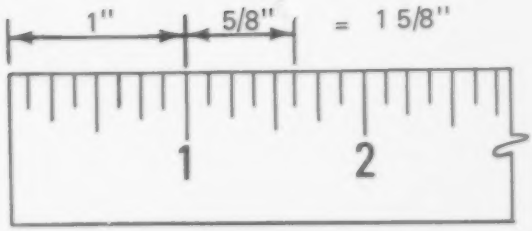
   c. Gain skill in determining divisions through practice

2. Determine inches and fractions of inches

   a. Count graduations in fractions of an inch beyond last full inch (Figure 1)

      EXAMPLE:

FIGURE 1



   b. Add fractions to last full inch

      (NOTE: In Figure 1, the total amount equals 1 5/8 inches.)

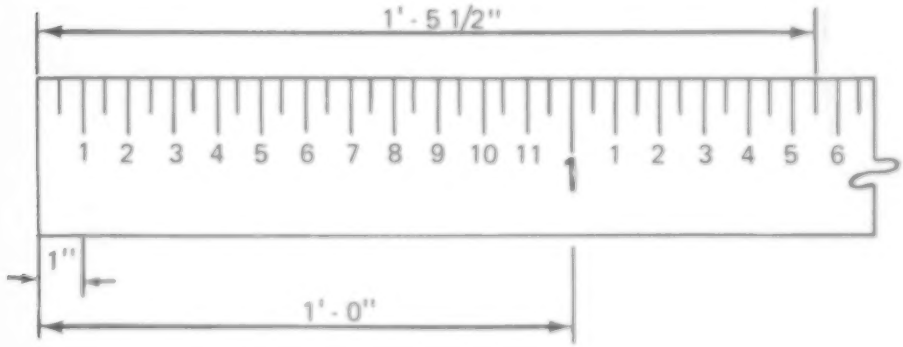
3. Reduce fraction if possible

INFORMATION SHEET

4. Determine feet, and add inches and fractions of an inch to obtain a correct measurement (Figure 2)

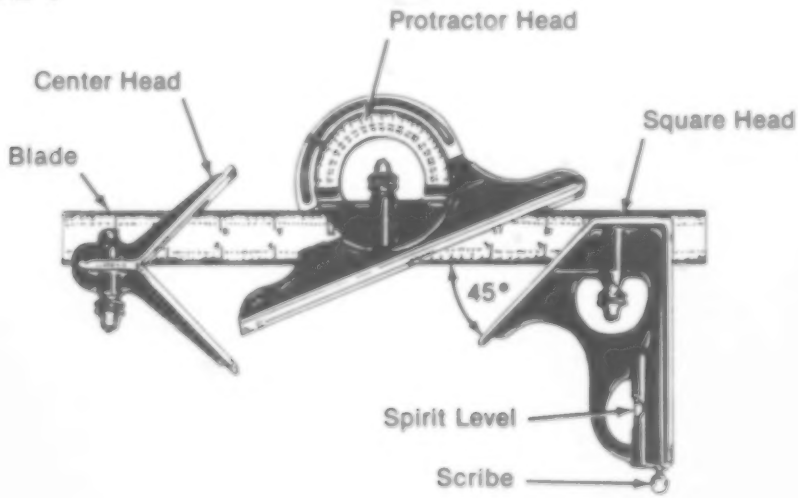
   EXAMPLE:

FIGURE 2



VI. Parts of a combination set (Figure 3)

FIGURE 3



VII. Uses of parts of a combination set

A. Blade — Measuring and laying out lines

B. Center head — Locating and laying out center of round objects

C. Protractor head — Testing, measuring, and laying out angles

INFORMATION SHEET

D. Square head — Used as a rule, height gauge, depth gauge, marking gauge, or plumb

(NOTE: Square head and blade used together becomes a combination square and may be used to lay out or test angles and to lay out parallel lines.)

E. Spirit level — Aiding in measuring angles in relation to vertical or horizontal plane; also used in conjunction with center head

F. Scribe — Marking

VIII. Types of calipers (Figures 4-8)

(NOTE: Micrometers are much more accurate than calipers. Always use micrometers in preference to calipers whenever practical.)

A. Spring-type outside

FIGURE 4

B. Spring-type inside

FIGURE 5

INFORMATION SHEET

C. Firm joint outside

FIGURE 6

D. Firm joint inside

FIGURE 7

E. Hermaphrodite

FIGURE 8

INFORMATION SHEET

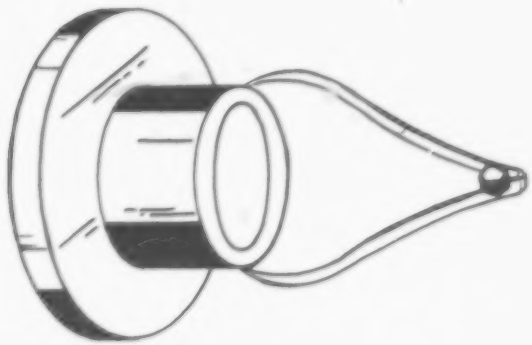
IX. Uses of types of calipers (Figures 9-11)

(NOTE: Calipers are made in a variety of sizes.)

A. Outside calipers — Gauging and determining outside diameters

EXAMPLE:

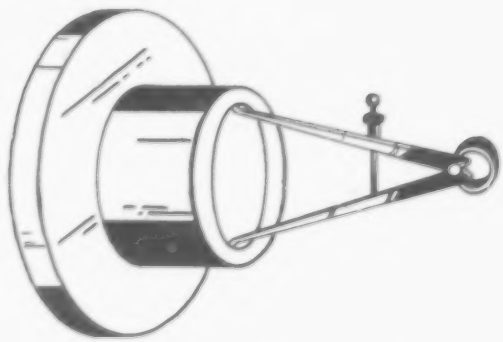
FIGURE 9



B. Inside calipers — Gauging and determining inside diameters

EXAMPLE:

FIGURE 10



INFORMATION SHEET

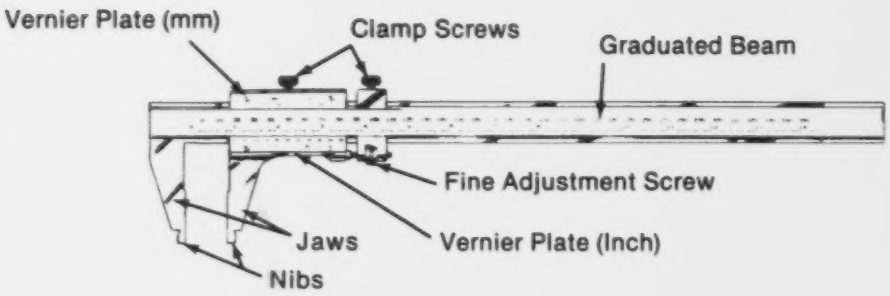
C. Hermaphrodite calipers — Scribing lines parallel to a surface and locating center points on circular objects

EXAMPLE:

FIGURE 11

X. Parts of a vernier caliper (Figure 12)

FIGURE 12



XI. Uses of a vernier caliper

(NOTE: The vernier caliper is a precision measuring tool.)

A. Measuring inside dimensions

B. Measuring outside dimensions

(NOTE: Some vernier calipers have a depth measuring rod.)

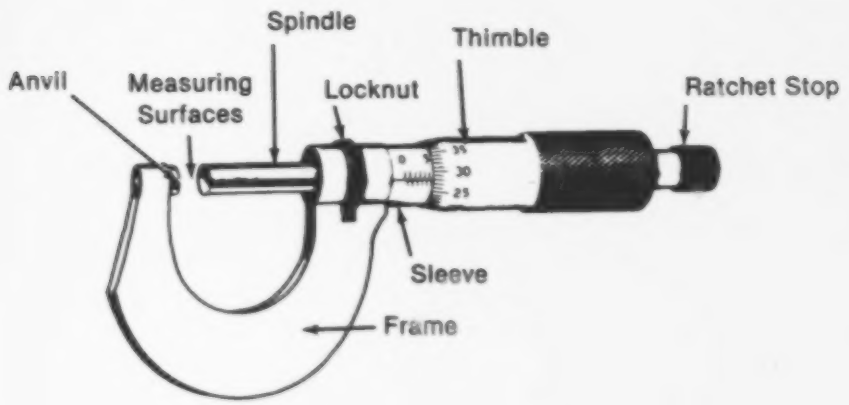
INFORMATION SHEET

C. Checking thickness

D. Checking or gauging inside and outside measurements

XII. Parts of an outside micrometer caliper (Figure 13)

FIGURE 13



XIII. Reading micrometer calipers (Figure 14; Assignment Sheets #4 and #5)

A. Inch micrometers are designed to measure accurately to 0.001 inch (one-thousandth of an inch)

B. Spindles are made with forty threads per inch, requiring thimble to be rotated forty complete revolutions to move spindle 1 inch

C. Each revolution moves spindle 0.025 inch (one-fortieth of an inch)

D. By dividing and marking thimble into twenty-five divisions, each mark on spindle becomes one-twenty fifth of a revolution or 0.001 inch (one-thousandth of an inch)

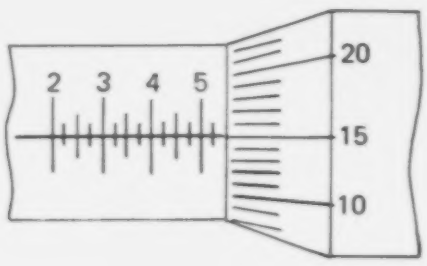
E. Markings on sleeve correspond to one full revolution of thimble, making them 0.025 inch apart

INFORMATION SHEET

F. Every fourth line is longer than others and marked 1, 2, 3, which is 0.100 inch, 0.200 inch, 0.300 inch

EXAMPLE:

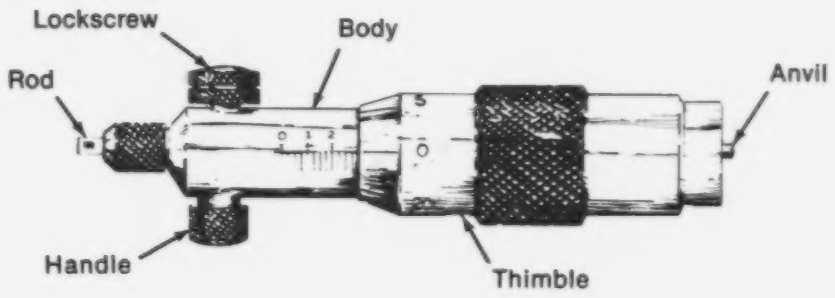
FIGURE 14



Five numbered graduations	= 0.500"
Two additional lines at 0.025 inch each	= 0.050"
Fifteenth line on thimble is aligned with index line on sleeve	= 0.015"
Total reading	= 0.565"

XIV. Parts of an inside micrometer caliper (Figure 15)

FIGURE 15



XV. Uses of the inside micrometer caliper (Transparencies #7 and #8)

A. Measuring inside diameter

EXAMPLES: Drilled holes, bored holes, reamed holes

INFORMATION SHEET

B. Measuring width

EXAMPLES: Slots, grooves

C. Measuring height

(NOTE: A base attachment should be used.)

D. Transferring measurements

XVI. Rules for use and care of precision instruments (Transparency #9)

A. Handle all precision instruments delicately

(NOTE: Do not abuse.)

B. Check accuracy of instrument periodically; observe for worn and loose parts

(NOTE: Follow manufacturer's instructions when adjusting.)

C. Keep instruments away from heat, abrasive dust, moisture, oil, and grease

D. Keep instruments and accessories in proper containers when not in use

E. Never use lubricant or water on dial indicators

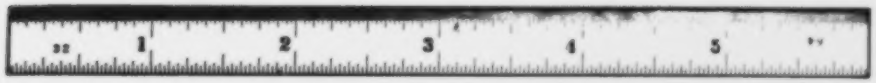
F. Never store outside micrometers with contact points touching

G. Do not overtighten instruments

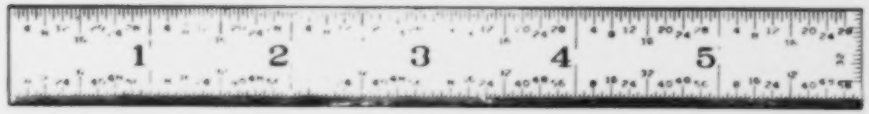
H. Always wipe off instruments before putting away

I. Use instruments only for intended use

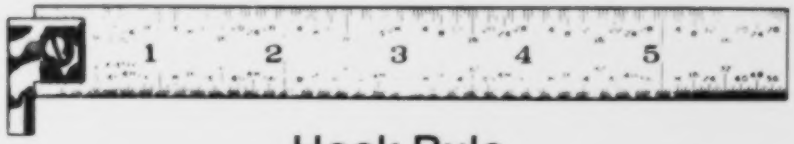
Measuring Tools



Narrow Flexible Rule



Steel Rule

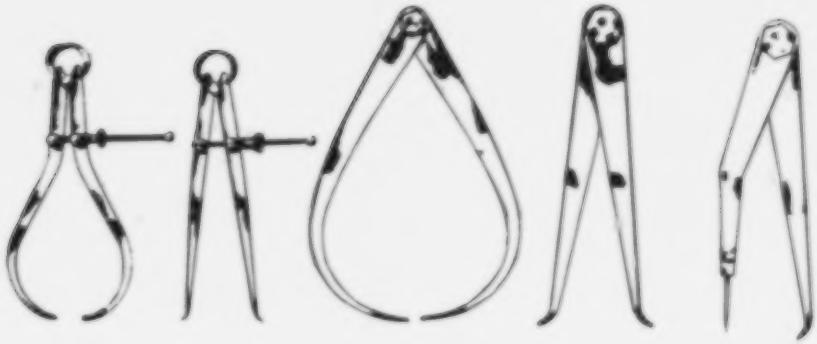


Hook Rule

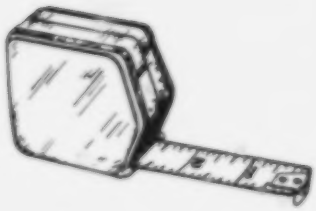
Short Rule with Holder

Vernier Caliper Rule

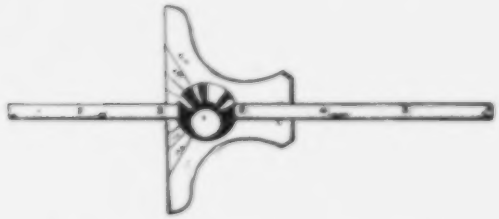
Measuring Tools
(Continued)



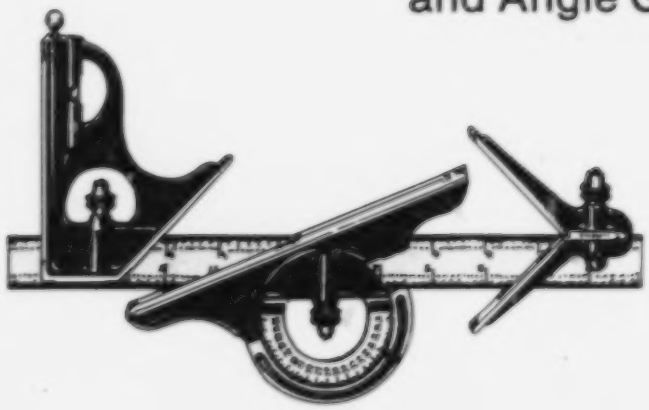
Calipers



Steel Tape

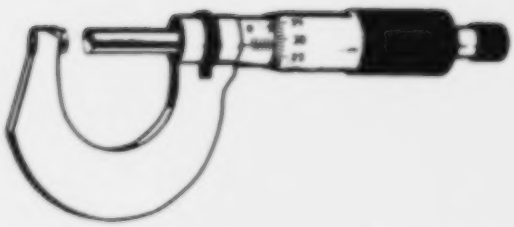


Combination Depth and Angle Gauge



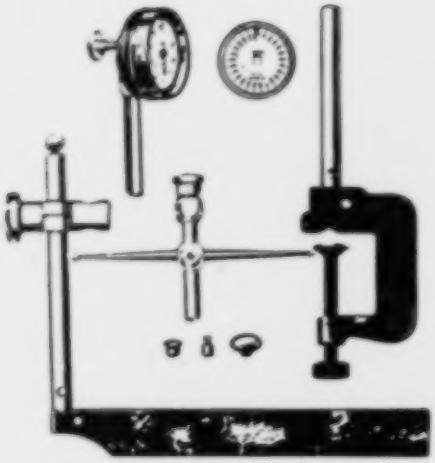
Combination Set

Measuring Tools
(Continued)

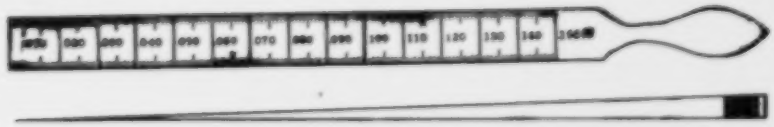


Outside Micrometer Caliper

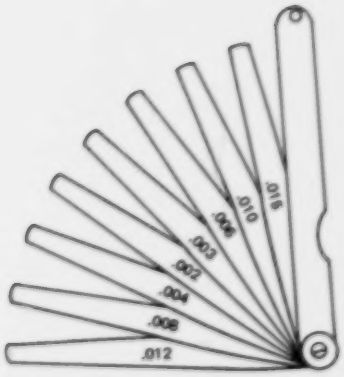
Inside Micrometer Caliper



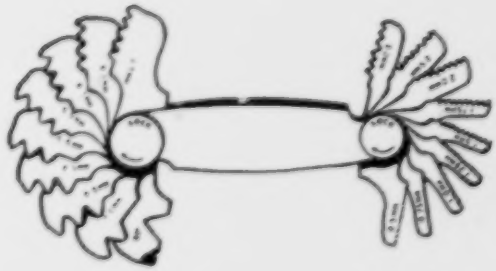
Dial Indicator Set



Taper Gauge

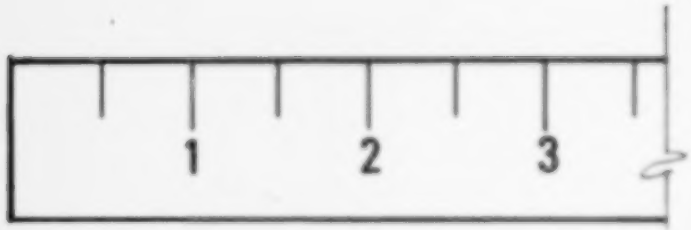


Feeler Gauge

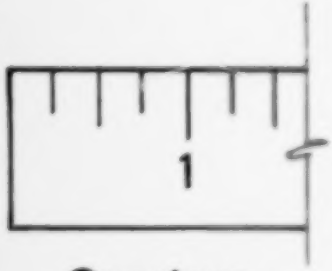


Screw Pitch Gauge

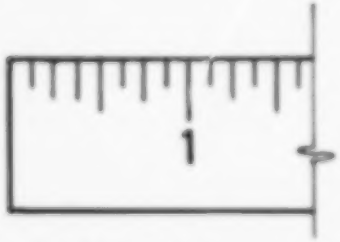
Graduations on a Rule



Halves



Quarters



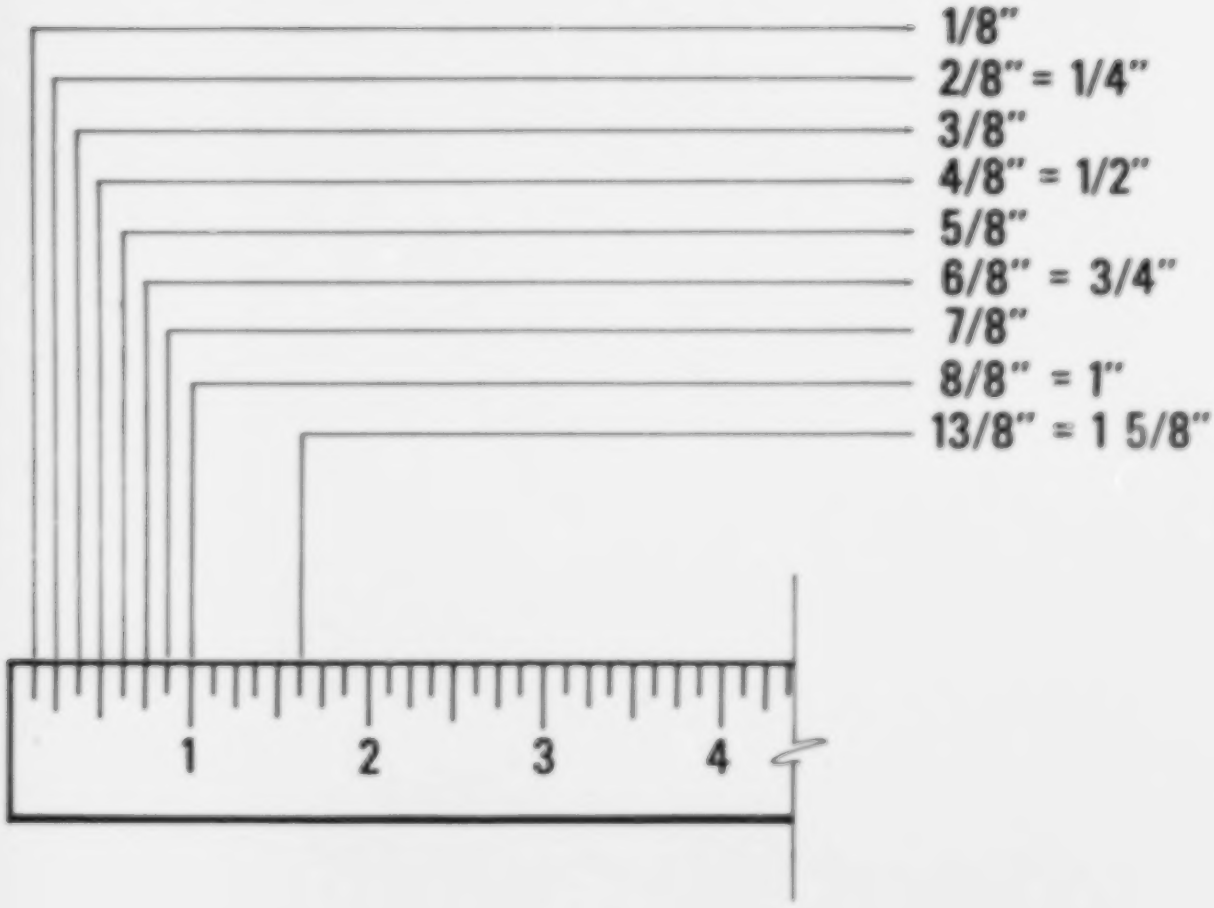
Eighths

Sixteenths

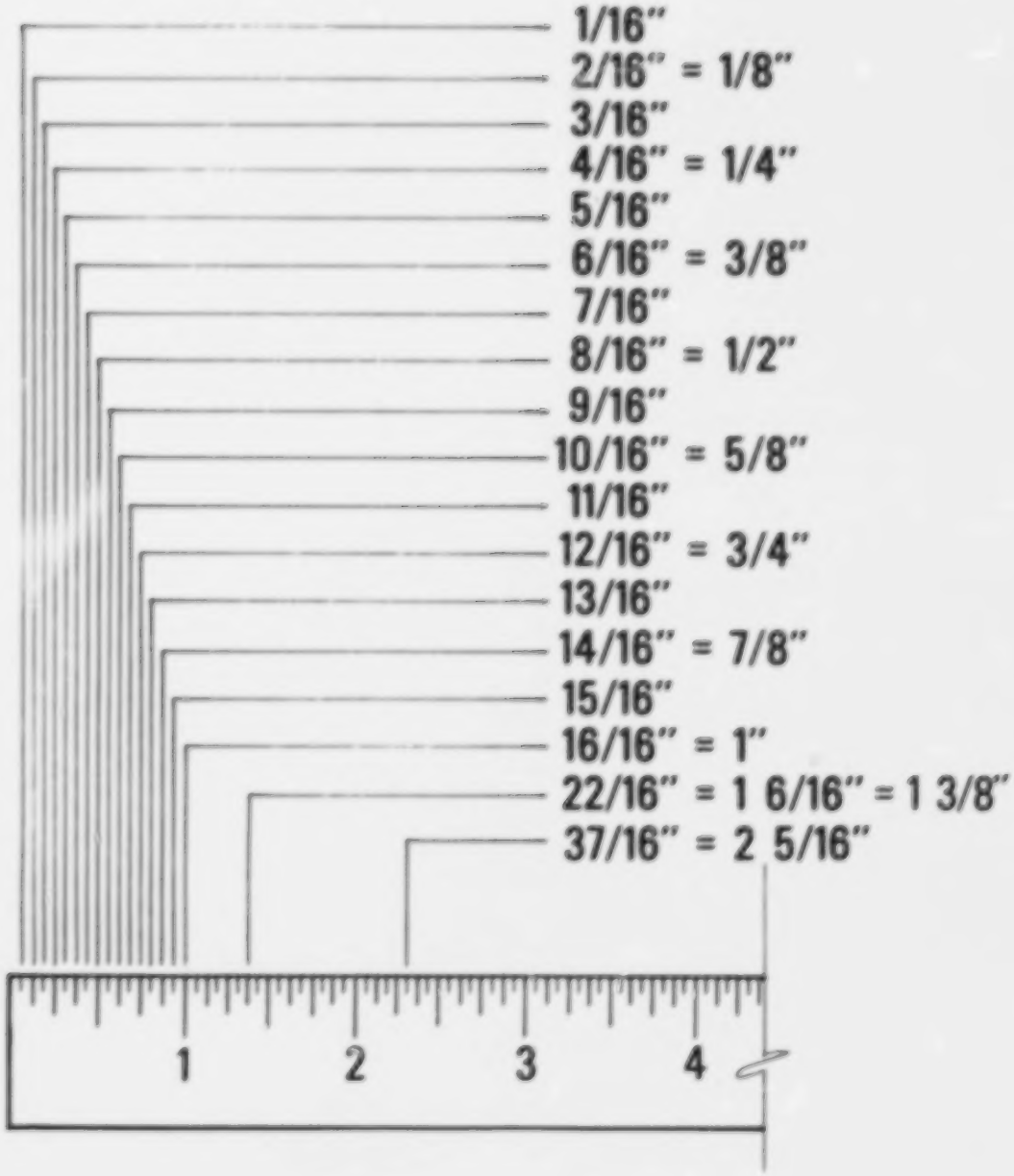
Thirty-Seconds

Graduations Applied to a Rule

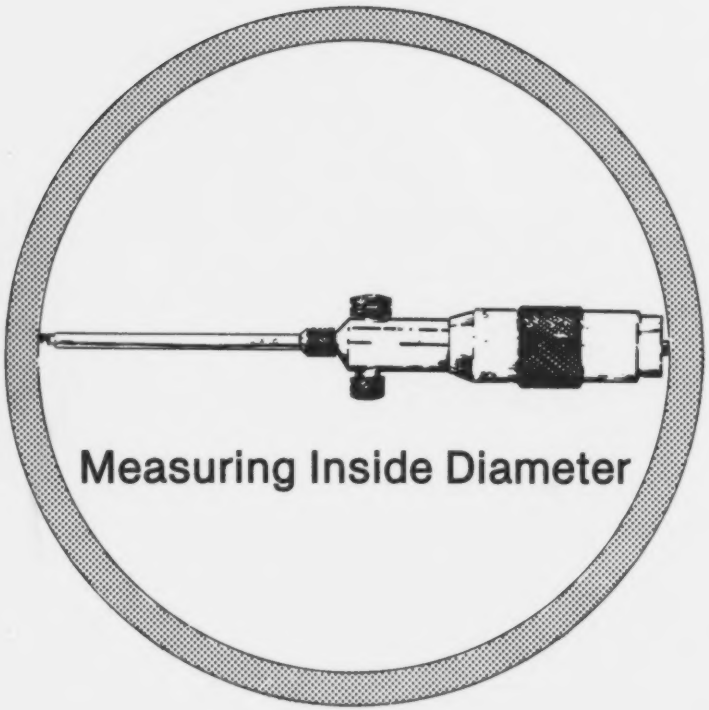
Reading the Eighths Rule



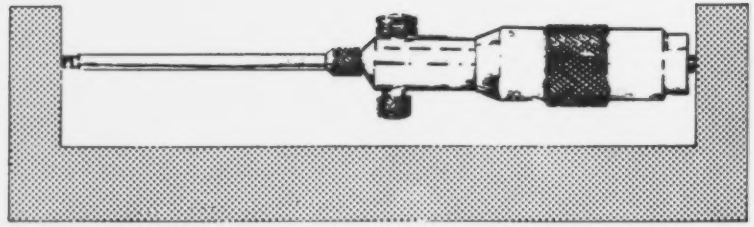
Reading the Sixteenths Rule



Uses of the Inside Micrometer Caliper



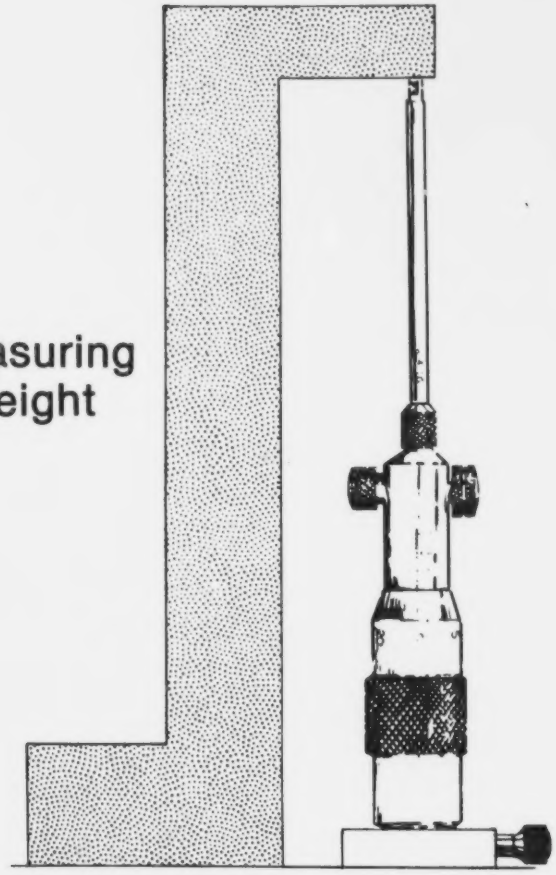
Measuring Inside Diameter

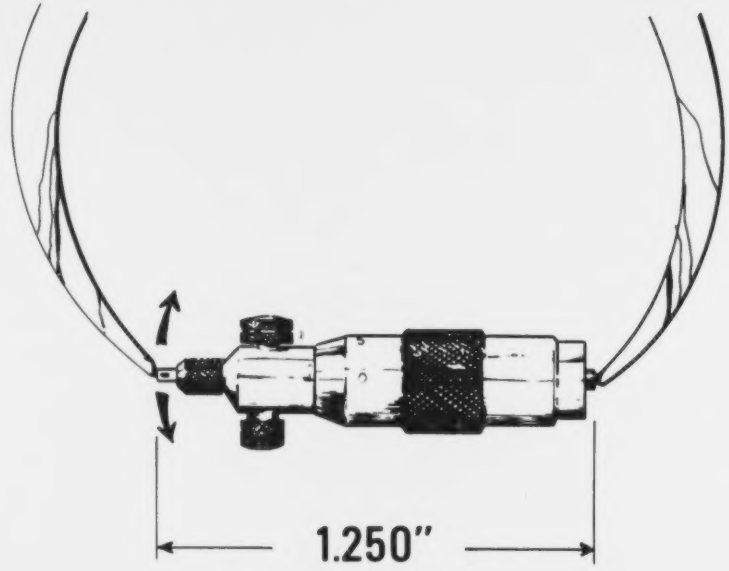


Measuring Width

Uses of the Inside Micrometer Caliper
(Continued)

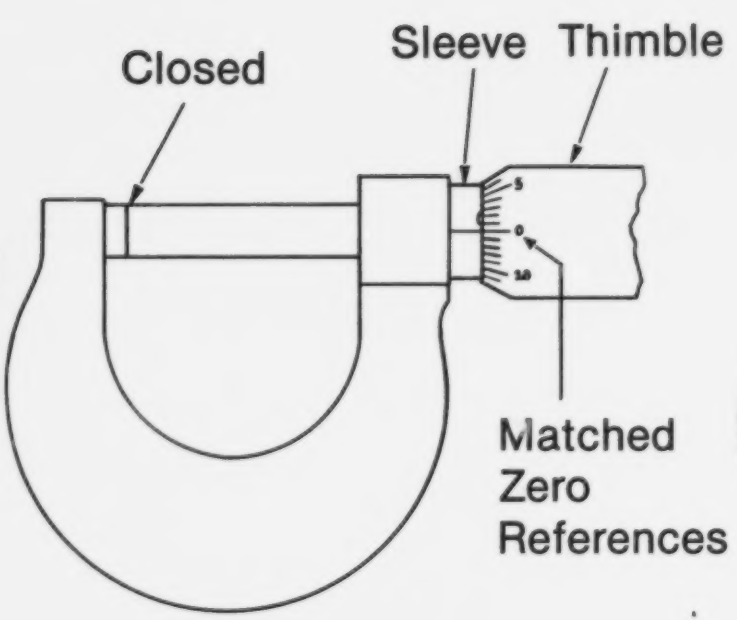
Measuring Height



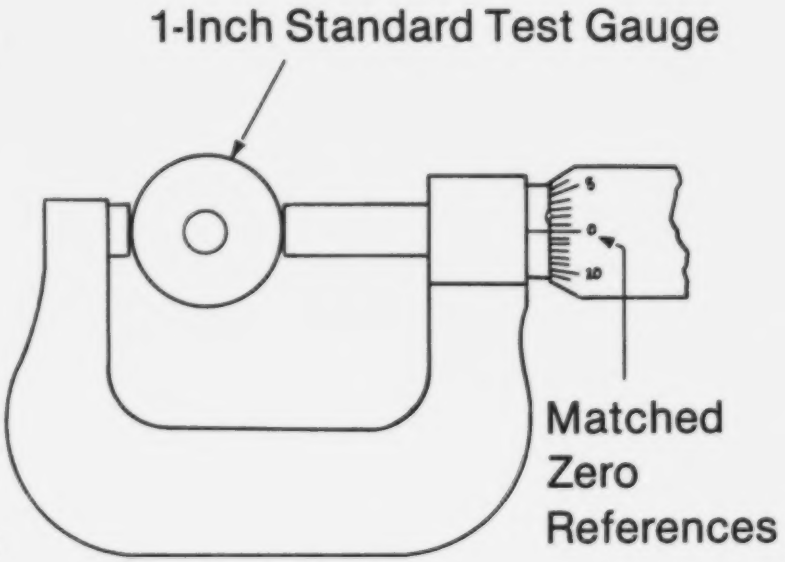


Transferring Measurement to Outside Spring-Joint Caliper

Checking the Micrometer for Accuracy



1-Inch Micrometer



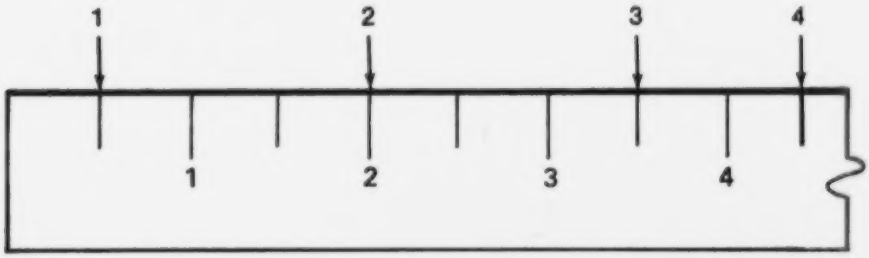
2-Inch Micrometer

MEASURING
UNIT III

ASSIGNMENT SHEET #1 — READ A RULE

NAME _____ SCORE _____

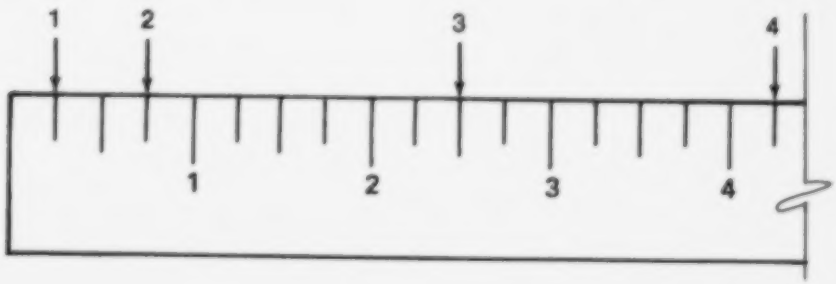
A. Read the following rule to the nearest ½ inch. Reduce fractions when possible.



1. _____
2. _____
3. _____
4. _____

ASSIGNMENT SHEET #1

B. Read the following rule to the nearest 1/4 inch. Reduce fractions when possible.



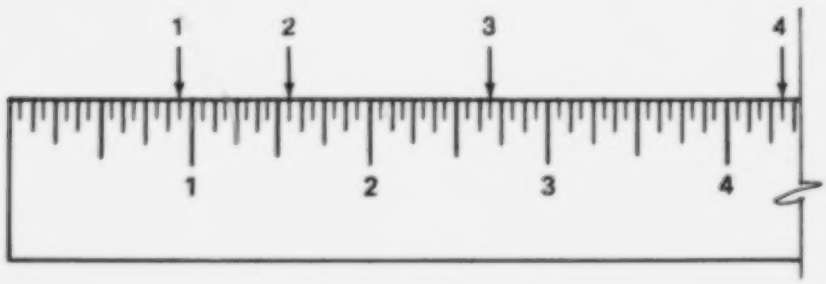
1. _____
2. _____
3. _____
4. _____

C. Read the following rule to the nearest 1/8 inch. Reduce fractions when possible.

1. _____
2. _____
3. _____
4. _____

ASSIGNMENT SHEET #1

D. Read the following rule to the nearest 1/16 inch. Reduce fractions when possible.



1. _____
2. _____
3. _____
4. _____

MEASURING
UNIT III

ASSIGNMENT SHEET #2 — DRAW LINES TO SPECIFIC LENGTHS

NAME _____ SCORE _____

Use the steel rule to draw straight lines to the following lengths.

A. 1 1/2 inches

B. 3 1/2 inches

C. 2 3/4 inches

D. 4 1/4 inches

E. 1 5/8 inches

F. 3 1/8 inches

G. 2 3/16 inches

H. 3 15/16 inches

I. 17/32 inches

J. 4 13/32 inches

K. 1 7/64 inches

L. 2 51/64 inches

MEASURING
UNIT III

ASSIGNMENT SHEET #3 — MEASURE LINES

NAME _____ SCORE _____

Measure the following lines to the specified graduation. Reduce fractions when possible. Write the correct answers on the lines.

A. Measure these lines to the nearest 1/4 inch.

1. _____
2. _____
3. _____

B. Measure these lines to the nearest 1/8 inch.

1. _____
2. _____
3. _____

C. Measure these lines to the nearest 1/16 inch.

1. _____
2. _____
3. _____

D. Measure these lines to the nearest 1/32 inch.

1. _____
2. _____
3. _____

E. Measure these lines to the nearest 1/64 inch.

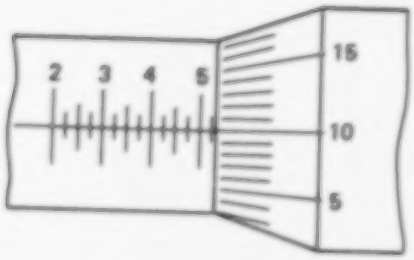
1. _____
2. _____
3. _____

MEASURING
UNIT III

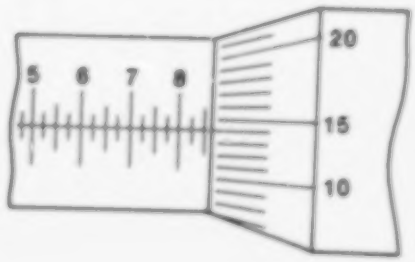
ASSIGNMENT SHEET #4 — READ AN OUTSIDE MICROMETER CALIPER

NAME _____ SCORE _____

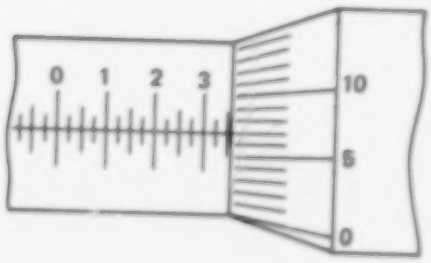
Read the following outside micrometer calipers to the nearest 0.001 inch (one-thousandth of an inch). Write the correct answers in the blanks.



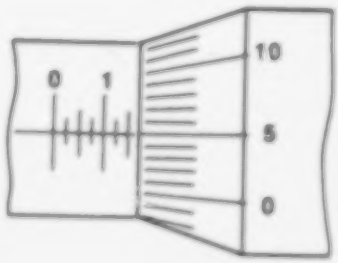
A. _____



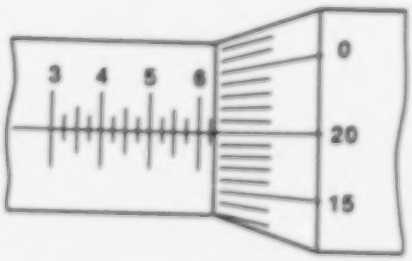
B. _____



C. _____



D. _____



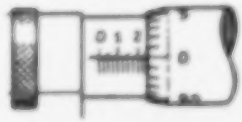
E. _____

MEASURING
UNIT III

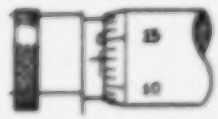
ASSIGNMENT SHEET #5 — READ AN INSIDE MICROMETER CALIPER

NAME _____ SCORE _____

Read the following inside micrometer calipers to the nearest 0.001 inch (one-thousandth of an inch). Write the correct answers in the blanks.

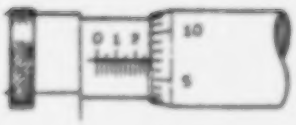


A. _____ B. _____



C. _____ D. _____

ASSIGNMENT SHEET #5



E. _____

MEASURING
UNIT III

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1

A.
1. 1/2 inch
2. 2 inches
3. 3 1/2 inches
4. 4 1/2 inches

B.
1. 1/4 inch
2. 3/4 inch
3. 2 1/2 inches
4. 4 1/4 inches

C.
1. 7/8 inch
2. 1 5/8 inches
3. 3 3/8 inches
4. 4 1/8 inches

D.
1. 15/16 inch
2. 1 9/16 inches
3. 2 11/16 inches
4. 4 5/16 inches

Assignment Sheet #2 — Evaluated to the satisfaction of the instructor

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #3

A. 1. 2 3/4 inches
   2. 1 1/4 inches
   3. 3 1/2 inches

B. 1. 3 7/8 inches
   2. 2 1/4 inches
   3. 1 1/8 inches

C. 1. 2 15/16 inches
   2. 1 3/8 inches
   3. 3 9/16 inches

D. 1. 1 inch
   2. 1 25/32 inches
   3. 2 3/16 inches

E. 1. 2 51/64 inches
   2. 2 5/16 inches
   3. 1 7/8 inches

Assignment Sheet #4

A. 0.535 inch

B. 0.864 inch

C. 0.357 inch

D. 0.155 inch

E. 0.645 inch

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #5

A. 0.871 inch

B. 0.250 inch

C. 0.500 inch

D. 0.013 inch

E. 0.282 inch

MEASURING
UNIT III

JOB SHEET #1 — CHECK AND ADJUST MICROMETER FOR ACCURACY

I. Tools

A. Micrometer

B. Spanner wrench

II. Procedure

A. Clean all dirt from contact faces

B. Bring faces together

C. Observe reading

D. Insert spanner wrench in small slot of sleeve (Figure 16)

FIGURE 16

Used with permission of the L. S. Starrett Company.

E. Turn sleeve until zero line coincides with zero line on thimble

F. Return tools to proper storage

MEASURING
UNIT III

JOB SHEET #2 — ADJUST MICROMETER TO ELIMINATE PLAY IN SPINDLE

I. Tools

A. Micrometer

B. Spanner wrench

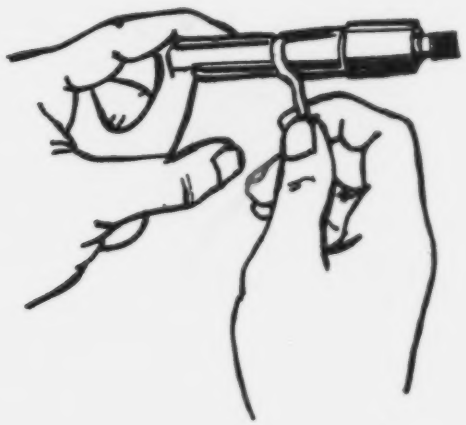
II. Procedure

A. Back off spindle

B. Insert spanner wrench

C. Tighten just enough to eliminate play (Figure 17)

FIGURE 17



Used with permission of the L. S. Starrett Company.

D. Return tools to proper storage

MEASURING
UNIT III

TEST

NAME _____ SCORE _____

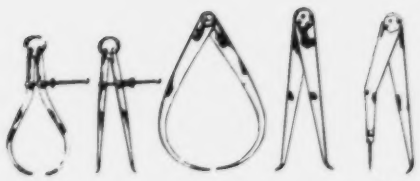
1. Match terms associated with measuring to their correct definitions. Write the correct numbers in the blanks.

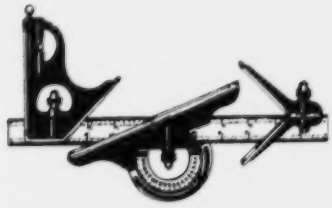
_____a.	Measuring instrument that can be adjusted to determine thickness, diameter, and distance between surfaces	1. Fraction
_____b.	Smallest whole unit of linear measure commonly used	2. Mic
_____c.	Unit of measure consisting of twelve equal parts or inches	3. Caliper
_____d.	One or more parts of a whole	4. Measuring
_____e.	Measuring instrument graduated in whole units and fractions of units	5. Dial indicator
_____f.	Checking predetermined dimensions	6. Dimension
_____g.	Number of full units and fractions of units between two points	7. Foot
_____h.	Abbreviation used for *micrometer*	8. Vernier
_____i.	Watchlike tool used to show dimensional changes between two parts; accurate to one-thousandth of an inch	9. Inch
_____j.	Short scale made to slide along divisions of a graduated instrument to indicate parts of divisions	10. Rule

TEST

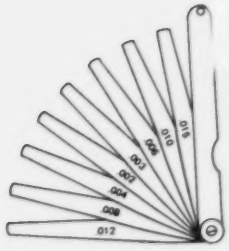
2. Identify the following types of measuring tools used in shop work. Write the correct names in the blanks.

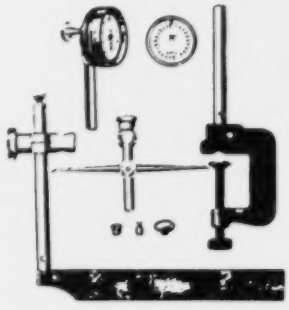
Steel rule	**Narrow flexible rule**	**Combination depth and angle gauge**
Hook rule	**Short rule with holder**	**Outside micrometer caliper**
Steel tape	**Vernier caliper rule**	**Inside micrometer caliper**
Calipers	**Combination set**	**Dial indicator set**
Taper gauge	**Feeler gauge**	**Screw pitch gauge**





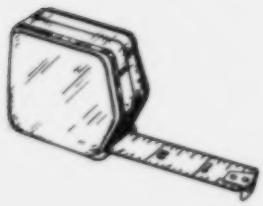
a. _____ b. _____

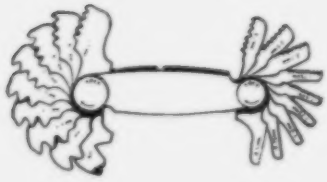




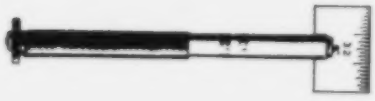
c. _____ d. _____

TEST

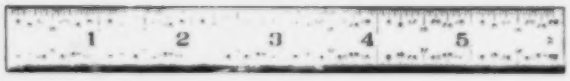


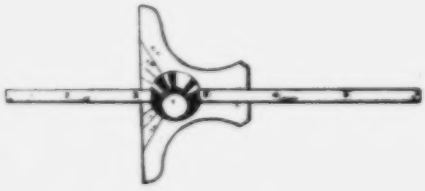


e. _____ f. _____



g. _____ h. _____

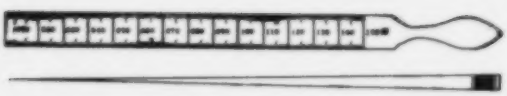




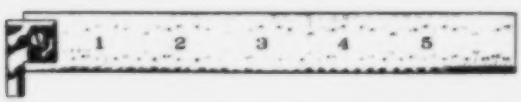
i. _____ j. _____

k. _____ l. _____

TEST



m. _____ n. _____



o. _____

3. State four guidelines for using rules.

a. _____

b. _____

c. _____

d. _____

4. List steps for reading the rule.

a. _____

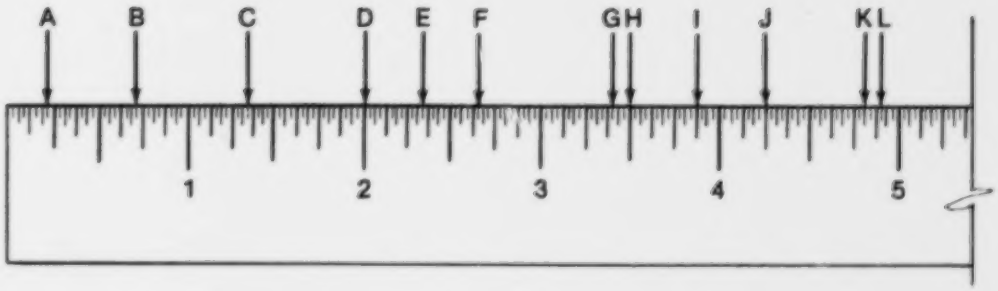
b. _____

c. _____

d. _____

TEST

5. Read the rule below to the nearest 1/32 of an inch. Reduce fractions when possible. Write the correct measurements in the blanks.



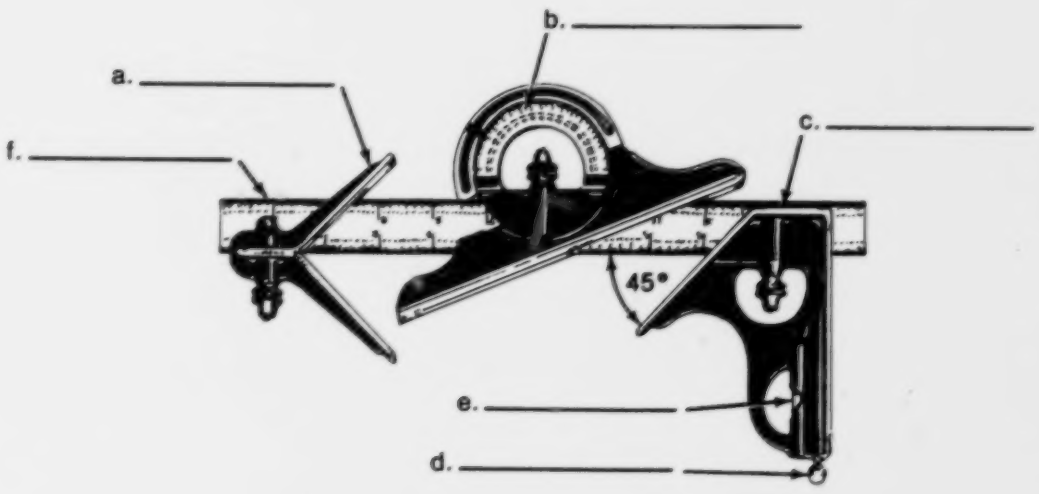
a. _____ e. _____ i. _____

b. _____ f. _____ j. _____

c. _____ g. _____ k. _____

d. _____ h. _____ l. _____

6. Label the parts of the combination set illustrated below.



TEST

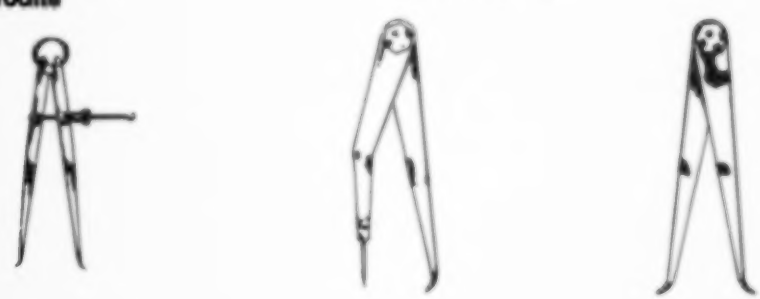
7. Match parts of a combination set to their correct uses. Write the correct numbers in the blanks.

_____a.	Testing, measuring, and laying out angles	1. Spirit level
_____b.	Locating and laying out center of round objects	2. Protractor head
_____c.	Measuring and laying out lines	3. Blade
_____d.	Aiding in measuring angles in relation to vertical or horizontal plane; also used in conjunction with center head	4. Square head
_____e.	Used as a rule, height gauge, depth gauge, marking gauge, or plumb	5. Center head
_____f.	Marking	6. Scribe

8. Identify the following types of calipers. Write the correct names in the blanks.

Spring-type outside
Firm joint outside
Hermaphrodite

Spring-type inside
Firm joint inside



a. _____ b. _____ c. _____

d. _____ e. _____

TEST

9. Describe the use of each type of calipers listed below.

   a. Outside calipers — _____

   _____

   b. Hermaphrodite — _____

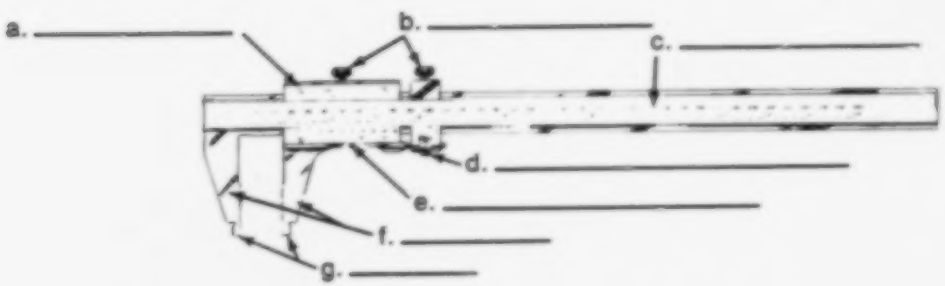
   _____

   c. Inside calipers — _____

   _____

10. Identify parts of the vernier caliper illustrated below. Write the correct names in the blanks.

Vernier plate (mm)
Clamp screws
Vernier plate (inch)
Nibs
Graduated beam
Fine adjustment screw
Jaws



11. Select from the following list uses of a vernier caliper. Write an "X" in the blank before each correct answer.

   _____a. Checking thickness

   _____b. Checking for square

   _____c. Measuring inside dimensions

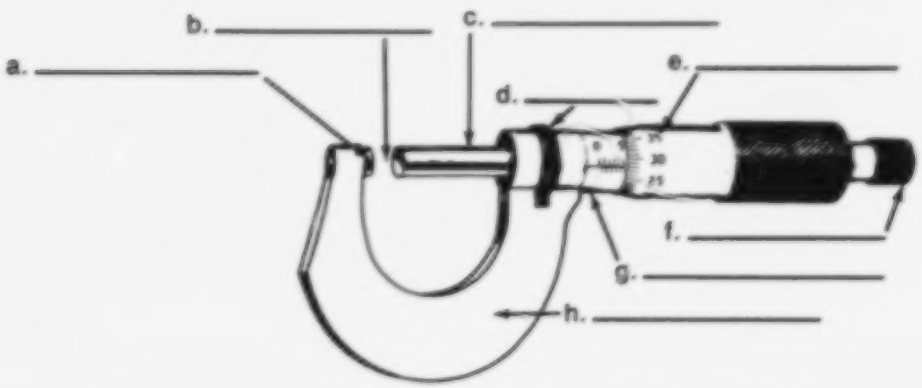
TEST

_____d. Checking or gauging inside and outside measurements

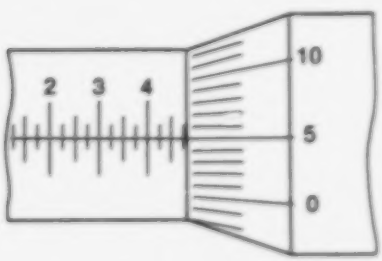
_____e. Measuring outside dimensions

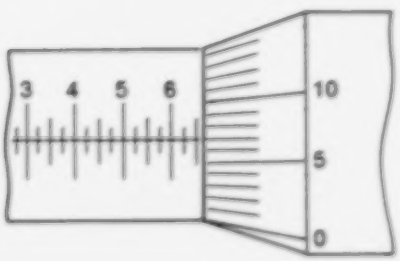
_____f. Checking plumb

12. Label the parts of the outside micrometer caliper illustrated below.



13. Read micrometer calipers, using the illustrations below. Write the correct measurements in the blanks.

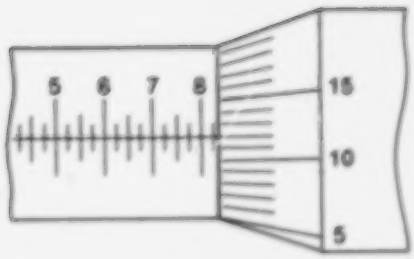




a. _____ inch

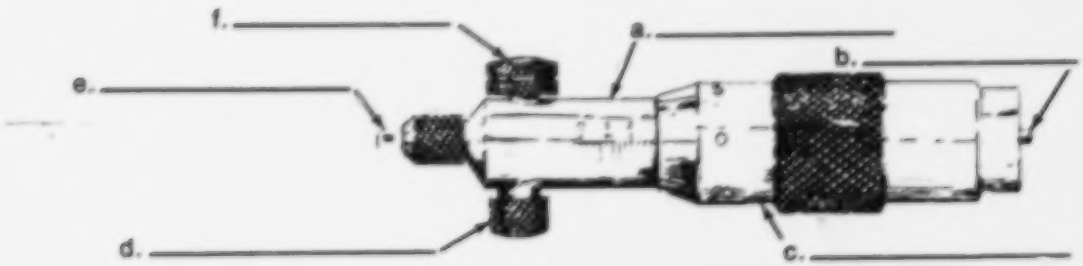
b. _____ inch

TEST



c. _____ inch

14. Label the parts of the inside micrometer caliper illustrated below.



15. Select from the following list uses of an inside micrometer caliper. Write an "X" in the blank before each correct answer.

_____a. Measuring height

_____b. Transferring measurments

_____c. Measuring outside diameter

_____d. Measuring thickness

_____e. Measuring width

_____f. Measuring inside diameter

TEST

16. List five rules for use and care of precision instruments.

a. _____

_____

b. _____

_____

c. _____

_____

d. _____

_____

e. _____

_____

(NOTE: Test question 17 lists the job sheets. They are an important part of this test. If they have not been completed, check with your instructor.)

17. Demonstrate the ability to

a. Check and adjust micrometer for accuracy.

b. Adjust micrometer to eliminate play in spindle.

MEASURING
UNIT III

ANSWERS TO TEST

1.

a.	3	f.	4
b.	9	g.	6
c.	7	h.	2
d.	1	i.	5
e.	10	j.	8

2.

a.	Calipers	i.	Steel rule
b.	Combination set	j.	Combination depth and angle gauge
c.	Feeler gauge	k.	Narrow flexible rule
d.	Dial indicator set	l.	Outside micrometer caliper
e.	Steel tape	m.	Taper gauge
f.	Screw pitch gauge	n.	Vernier caliper rule
g.	Inside micrometer caliper	o.	Hook rule
h.	Short rule with holder		

3. Answer should include any four of the following

   a. Use proper length and graduation

   b. Use finest graduation for accuracy

   c. Use a good quality rule

   d. Never bend or distort a rule

   e. Use 1-inch graduation as reference for accuracy

   f. Use rule on edge for better reading

   g. Use rule along axis, parallel to plane of measurement

ANSWERS TO TEST

4. a. Select scale of required unit
   b. Total number of graduations
   c. Count whole units
   d. Reduce graduations to lowest terms

5. a. 7/32 inch
   b. 23/32 inch
   c. 1 11/32 inches
   d. 2 inches
   e. 2 11/32 inches
   f. 2 21/32 inches
   g. 3 13/32 inches
   h. 3 1/2 inches
   i. 3 7/8 inches
   j. 4 1/4 inches
   k. 4 13/16 inches
   l. 4 29/32 inches

6. a. Center head
   b. Protractor head
   c. Square head
   d. Scribe
   e. Spirit level
   f. Blade

7. a. 2
   b. 5
   c. 3
   d. 1
   e. 4
   f. 6

8. a. Spring-type inside
   b. Hermaphrodite
   c. Firm joint inside
   d. Firm joint outside
   e. Spring-type outside

9. Description should include the following
   a. Outside calipers — Gauging and determining outside diameters
   b. Hermaphrodite — Scribing lines parallel to a surface and locating center points on circular objects
   c. Inside calipers — Gauging and determining inside diameters

ANSWERS TO TEST

10. a. Vernier plate (mm)
    b. Clamp screws
    c. Graduated beam
    d. Fine adjustment screw
    e. Vernier plate (inch)
    f. Jaws
    g. Nibs

11. a, c, d, e

12. a. Anvil
    b. Measuring surfaces
    c. Spindle
    d. Locknut
    e. Thimble
    f. Ratchet stop
    g. Sleeve
    h. Frame

13. a. 0.480 inch
    b. 0.657 inch
    c. 0.837 inch

14. a. Body
    b. Anvil
    c. Thimble
    d. Handle
    e. Rod
    f. Lockscrew

15. a, b, e, f

16. Answer should include any five of the following
    a. Handle all precision instruments delicately
    b. Check accuracy of instrument periodically; observe for worn and loose parts
    c. Keep instruments away from heat, abrasive dust, moisture, oil, and grease
    d. Keep instruments and accessories in proper containers when not in use
    e. Never use lubricant or water on dial indicators

ANSWERS TO TEST

f. Never store outside micrometers with contact points touching

g. Do not overtighten instruments

h. Always wipe off instruments before putting away

i. Use instruments only for intended use

17. Performance skills evaluated to the satisfaction of the instructor

BASIC RIGGING AND HOISTING
UNIT IV

UNIT OBJECTIVE

After completing this unit, the student should be able to rig and handle loads, using safe rigging practices. The student will show this knowledge by completing assignment sheets, job sheets, and unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match to their correct definitions terms associated with rigging and hoisting.
2. State safety tips related to rigging and hoisting.
3. Label types of hoisting devices.
4. Select from a list good rigging practices.
5. State effects of lacing rather than reeving blocks.
6. Identify sheave bearing configurations.
7. List factors involved in selecting blocks and reeving for a particular application.
8. Discuss the mechanical advantage of any multiple-part reeved system.
9. Define *sheave friction*.
10. Name minimum and maximum sheave groove tolerances for specific rope diameters.
11. Calculate safe working load (SWL) of different types and sizes of rope.
12. Calculate safe working load (SWL) of different sizes of wire rope.
13. State the importance of spreading angles.
14. Calculate sling stress.
15. Arrange in order steps to take when performing maintenance on wire rope.
16. Identify types of snatch blocks.
17. Select from a list types of rigging hardware.

OBJECTIVE SHEET

18. Demonstrate the ability to

    a. Install wire rope clips.

    b. Rig and handle different types of loads.

BASIC RIGGING AND HOISTING
UNIT IV

SUGGESTED ACTIVITIES

I. Suggested activities

A. Gather equipment and materials for job sheet demonstrations.

B. Obtain transparencies.

(NOTE: Transparencies are available from AGC and CIMC.)

C. Provide students with objective sheet.

D. Discuss unit and specific objectives.

E. Provide students with information, assignment, and job sheets.

F. Discuss information and assignment sheets.

G. Demonstrate and discuss procedures outlined in job sheets.

H. Give test.

I. Complete appropriate section of competency profiles.

(NOTE: Competency profiles are available from AGC and CIMC.)

II. Instructional materials

A. Objective sheet

B. Suggested activities

C. Information sheet

D. Transparency masters

1. TM #1 — Block Reeving
2. TM #2 — Parts of Line and Mechanical Advantage
3. TM #3 — Factors to Account for Sheave Friction Loads
4. TM #4 — Factors to Account for Sheave Friction Loads (Continued)
5. TM #5 — Factors to Account for Sheave Friction Loads (Continued)
6. TM #6 — Matching Ropes and Sheaves

7. TM #7 — Effects of Improper Matching of Ropes and Sheaves

8. TM #8 — Safe Working Load (SWL) for Rope

9. TM #9 — Safe Working Load (SWL) for Wire Rope

10. TM #10 — Sling Angles and Load Factors

11. TM #11 — Sling Angle

12. TM #12 — Formula for Calculating Sling Stress

E. Assignment sheets

1. Assignment Sheet #1 — Calculate Safe Working Load (SWL) of Different Types and Sizes of Rope

2. Assignment Sheet #2 — Calculate Safe Working Load (SWL) of Different Sizes of Wire Rope

3. Assignment Sheet #3 — Calculate Sling Stress

F. Answers to assignment sheets

G. Job sheets

1. Job Sheet #1 — Install Wire Rope Clips

2. Job Sheet #2 — Rig and Handle Different Types of Loads

H. Test

I. Answers to test

III. Unit references

A. *Ausco Jacks and Automotive Service Equipment Catalog 176.* St. Joseph, Missouri: Auto Specialties Manufacturing Co., 1981.

B. *Coffing Hoists/Complete Line Catalog 174.* Charlotte, North Carolina: Duff-Norton Company, Inc., 1979.

C. Dickie, D. E. *Rigging Manual,* 4th ed. Toronto, Ontario, Canada: Construction Safety Association of Ontario, 1979.

SUGGESTED ACTIVITIES

D. Hendrix, Laborn J. "Bud". *Heavy Equipment Operator Instructional Materials*, Volume I. Stillwater, Oklahoma: Oklahoma State Department of Vocational and Technical Education/Curriculum and Instructional Materials Center and The Associated General Contractors of America, 1981.

E. Newberry, W. G. (Bill). *Handbook for Riggers*, 2nd ed. Canada: Printed in Canada, ISBNO-9690154-1-0, 1977.

BASIC RIGGING AND HOISTING
UNIT IV

INFORMATION SHEET

I. Terms and definitions

A. Becket — Part of line in block and tackle that is attached to block

B. Block — One or more sheaves fitted in a frame supported by a hook or shackle inserted in the block strap

C. Center of gravity — That point at which entire weight of a load may be concentrated so that if supported at this point the load would remain balanced

D. Choker — Rope or cable with eyes spliced on each end, or an eye and hook; used to secure loads that are being hoisted

E. Hitch — To attach a rope to a post, pole, ring, hook, or other object

F. Mechanical advantage — Amount by which the machine multiplies the force applied to it in order to lift or move a load

G. Reeved blocks — Two blocks attached with an attaching rope or cable that is laced through the sheaves on both blocks until all sheaves are used and end of rope or cable hangs loose as the lead line

(NOTE: A multiple-part reeved system is a device or machine through which the lead line pull is multiplied to lift the load, thus gaining a mechanical advantage.)

H. Rigging — Setting up block and tackle to winch; stacking and hoisting material and equipment, or replacing cables on equipment

I. Shackle — Connecting device for lines and drawbars; u-shaped and pierced for a cross bolt or pin

J. Sheave — Grooved wheel or pulley

K. Splice — To join two sections of rope or cable to form a continuous length

L. Tackle — Assembly of blocks and lines used to gain a mechanical advantage in lifting

M. Tagline — Rope used to guide or steady a load while it is being lifted

N. Thimble — Grooved metal ring inserted in loop of rope to prevent wear

II. Safety tips related to rigging and hoisting

A. Use personal protective devices such as goggles, gloves, safety shoes, and hard hat

B. Use tagline to guide or steady load

C. Do not walk under load

INFORMATION SHEET

D. Be sure that load is balanced properly

E. Do not overload hoist, chokers, or slings

F. Lubricate slings and cables to prevent rust

G. Be sure that all hooks have safety snaps

H. Know your equipment's maximum operating capacity

I. Know and respond to hand signals

J. Be sure that all safety devices function properly

K. Operate hoist controls smoothly

L. Be sure that all safety guards are in their proper places

M. Keep equipment clean and in good working order

N. Test load for proper rigging before lifting it

O. Inspect chains and cables regularly

III. Types of hoisting devices (Figures 1-13)

(NOTE: In the field, several pieces of equipment may be used for hoisting: crane, backhoe, forklift, and others.)

A. Simple block and tackle

FIGURE 1

B. Cable lever unit (winch hoist)

FIGURE 2

INFORMATION SHEET

C. Chain lever hoist

FIGURE 3

D. Hand chain hoist

FIGURE 4

E. Typical spur-geared chain hoist

FIGURE 5

F. Typical screw-geared chain hoist

FIGURE 6

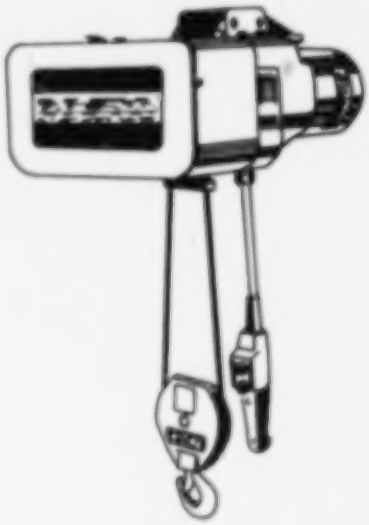
INFORMATION SHEET

G. Typical differential-type chain hoist

FIGURE 7

H. Electric cable hoist

FIGURE 8



I. Electric chain hoist

FIGURE 9

J. Pedestal-type hand winch

FIGURE 10

INFORMATION SHEET

K. Portable gantry crane

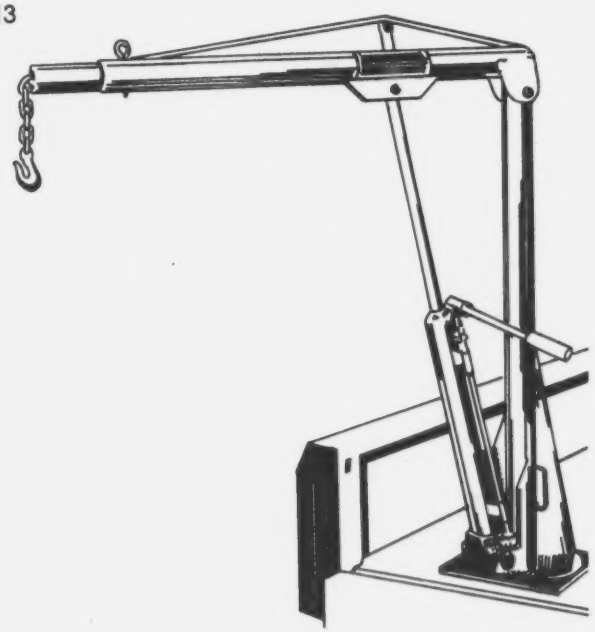
FIGURE 11

L. Mobile hydraulic shop crane

FIGURE 12

M. Truck-mounted hydraulic crane

FIGURE 13



INFORMATION SHEET

IV. Good rigging practices

A. Turn hooks out

B. Use shackles on chokers where there may be cutting action

C. Always make vertical lifts on eyebolts

(NOTE: Lifting at an angle reduces safe load as much as 90 percent.)

D. Use thimble in eye splices

E. Use shackles whenever two or more ropes are to be used over a hook

F. Use tagline to control load

G. Secure all unused sling lines

H. Never wrap rope around a hook

I. Do not permit bending of rope near a splice or attached fitting

J. Never allow a shackle to be pulled at an angle

(NOTE: Use washers for packing if necessary.)

K. Do not use screw-pin shackle if the pin can roll under load and unscrew

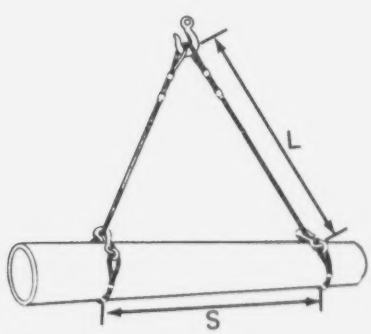
L. Center lifting device over load before lifting

M. Be sure to use pads under cables at sharp corners and edges

N. For proper sling angle, be sure that length of sling is always greater than span between the two connections (Figure 14)

EXAMPLE: L (length of sling) is greater than S (span)

FIGURE 14



INFORMATION SHEET

V. Effects of lacing rather than reeving blocks (Transparency #1)

(NOTE: Whenever possible, use right-angle reeving and be sure that blocks are identical and square in relation to each other. It is very important that the becket connection be properly made and attached.)

A. Tendency to tilt when running empty

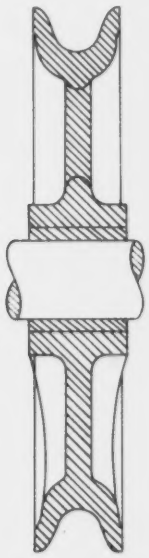
B. Excessive wear

C. Damage to sheaves and rope

VI. Sheave bearing configurations (Figures 15-19)

A. Plain-bore sheave

FIGURE 15



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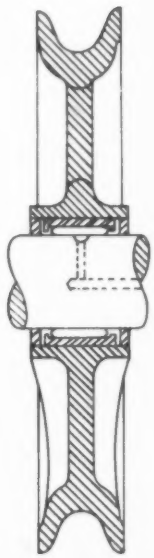
INFORMATION SHEET

B. Roller-bushed sheave

FIGURE 16



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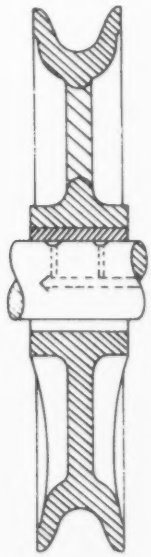
C. Pressure-lubricated bronze-bearing sheave

FIGURE 17



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INFORMATION SHEET

D. Roller-bearing sheave

FIGURE 18

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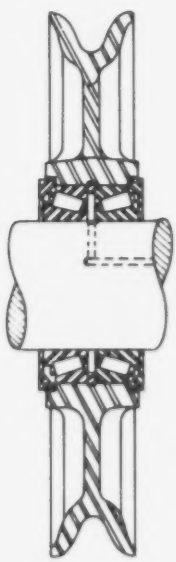
E. Roller/thrust-bearing sheave

FIGURE 19



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INFORMATION SHEET

VII. Factors involved in selecting blocks and reeving for a particular application

A. Working load

B. Connections

C. Sheaves

D. Pins

E. Structural details

F. Mechanical advantage required

(NOTE: The block size, rope size, and number of sheaves per block must be determined in relationship to the load to be lifted and the pull that can be applied to the lead line.)

VIII. Mechanical advantage of any multiple-part reeved system — is always equal to the number of parts of line supporting the running block and the load, excluding lead line (Transparency #2)

(NOTE: The increase in load-carrying ability is accompanied by a corresponding decrease in speed of travel. The lead line must move four times as fast as the load for a mechanical advantage of 4. Travel of the lead line divided by travel of the load is also a measure of mechanical advantage.)

IX. Sheave friction — Loss or decrease in mechanical advantage as rope passes over sheaves (Transparencies #3-#5)

EXAMPLES: Plain-bore sheaves — 10 percent loss
Bronze bushings — 5 percent loss
Roller bearings — 3 percent loss

(NOTE: When the load is lifted, each sheave introduces a friction force equal to either 10 percent, 5 percent, or 3 percent of the load it is carrying, depending on the sheave bearings and how easily they rotate.)

X. Sheave groove tolerances for specific rope diameters (Table 1; Transparencies #6 and #7)

TABLE 1

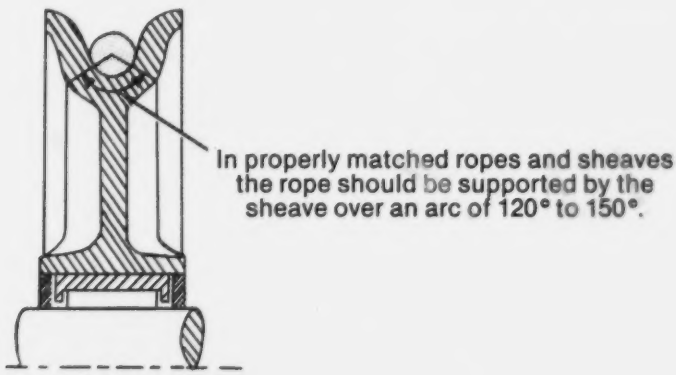
Rope Diameter	Minimum	Maximum
1/4 to 5/16-inch	1/64-inch	1/32-inch
3/8 to 3/4-inch	1/32-inch	1/16-inch
13/16 to 1 1/8-inch	3/64-inch	3/32-inch
1 3/16 to 1 1/2-inch	1/16-inch	1/8-inch
1 9/16 to 2 1/4-inch	3/32-inch	3/16-inch
2 5/16-inch and up	1/8-inch	1/4-inch

INFORMATION SHEET

(NOTE: The bottom of the groove should have an arc of support of at least 120 degrees to 150 degrees, and the sides of the groove should be tangent to the arc. See Figure 20.)

EXAMPLE:

FIGURE 20



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XI. Formulas for calculating safe working load (SWL) of different types and sizes of rope (Transparency #8; Assignment Sheet #1)

(NOTE: Each formula uses its own mathematical constant, a number assumed to have one value throughout the particular formula.)

A. Manila rope

1. Change diameter of rope to eighths
2. Square numerator and multiply by 20 (mathematical constant)

EXAMPLE: $\frac{1}{2}$-inch manila rope = $\frac{4}{8}$-inch diameter

SWL = 4 x 4 x 20 = 320 pounds

B. Nylon or polyester rope

1. Change diameter of rope to eighths
2. Square numerator and multiply by 60 (mathematical constant)

EXAMPLE: $\frac{5}{8}$-inch nylon or polyester rope = $\frac{5}{8}$-inch diameter

SWL = 5 x 5 x 60 = 1,500 pounds

INFORMATION SHEET

C. Polypropylene rope

1. Change diameter of rope to eighths

2. Square numerator and multiply by 40 (mathematical constant)

EXAMPLE: $\frac{3}{4}$-inch polypropylene rope = $\frac{6}{8}$-inch diameter

SWL = 6 × 6 × 40 = 1,440 pounds

D. Polyethylene rope

1. Change diameter of rope to eighths

2. Square numerator and multiply by 35 (mathematical constant)

EXAMPLE: 1-inch polyethylene rope = $\frac{8}{8}$-inch diameter

SWL = 8 × 8 × 35 = 2,240 pounds

XII. Formula for calculating safe working load (SWL) of different sizes of wire rope (Transparency #9; Assignment Sheet #2)

(NOTE: Compute safe working load in tons. The number "8" is a mathematical constant.)

Formula: SWL (Tons) = Rope Diameter × Rope Diameter × 8

EXAMPLE: $\frac{1}{2}$-inch diameter wire rope

$$SWL = \frac{1}{2} \times \frac{1}{2} \times 8$$

$$= 2 \text{ tons}$$

XIII. Importance of spreading angles (Figure 21; Transparencies #10 and #11)

A. Changing angle of sling leg may increase stress on sling

B. As the angle is reduced, lifting capacity is reduced very rapidly

C. When single leg of sling is at 60-degree angle, lifting capacity is only 87 percent of that of a vertical leg

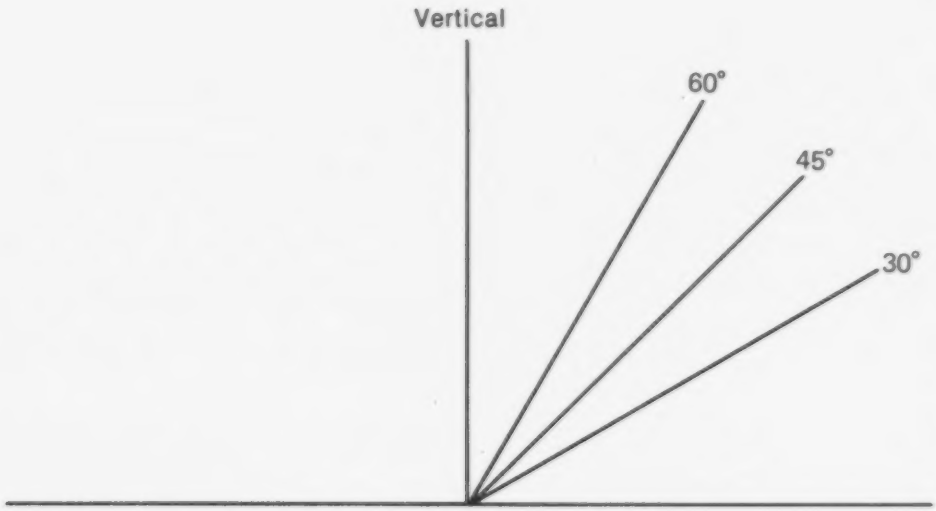
INFORMATION SHEET

D. When single leg of sling is at 45-degree angle, lifting capacity is only 71 percent of that of a vertical leg

E. When single leg of sling is at 30-degree angle, lifting capacity is only 50 percent of that of a vertical leg

EXAMPLE:

FIGURE 21



INFORMATION SHEET

XIV. Formula for calculating sling stress (Figure 22; Transparency #12; Assignment Sheet #3)

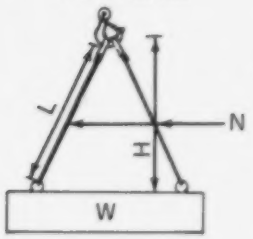
Formula: $S = \frac{W \times L}{H \times N}$

Where W = Weight of load
L = Length of sling
H = Height of slings
N = Number of sling legs
S = Sling stress

EXAMPLE: $S = \frac{W \times L}{H \times N}$

Where W = 10 tons
L = 6 feet
H = 4 feet
N = 2

FIGURE 22



$S = \frac{10 \times 6}{2 \times 4}$

$= \frac{60}{8}$

= 7 ½ tons each sling

XV. Steps to take when performing maintenance on wire rope

(NOTE: Frequent application of proper lubricant to the exterior of the rope is necessary to help retain lubricant within the rope.)

A. Check for frayed or worn wires

B. Heat oil recommended by manufacturer

(NOTE: Apply oil while heated and thin so that it will penetrate into center of rope.)

C. Apply oil by moving rope through a long pan filled with oil

D. Wipe off surplus oil as rope leaves pan

E. Let rope cool so that oil thickens

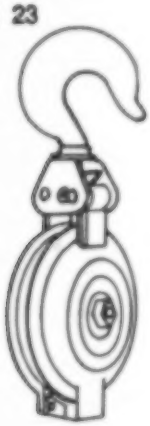
INFORMATION SHEET

XVI. Types of snatch blocks (Figures 23-28)

(NOTE: Snatch blocks are used to increase the force exerted by a line when hoisting and dragging.)

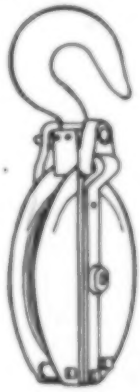
A. Swivel hook

FIGURE 23



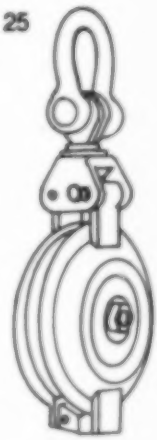
B. Self-locking

FIGURE 24



C. Swivel shackle

FIGURE 25



D. Swivel eye

FIGURE 26

E. Drop link

FIGURE 27

F. Upset swivel shackle

FIGURE 28

INFORMATION SHEET

XVII. Types of rigging hardware (Figures 29-48)

A. Safety hook

EXAMPLE:

FIGURE 29

B. Slip hook

EXAMPLE:

FIGURE 30

C. Grab hook

EXAMPLE:

FIGURE 31

D. Chain slip hook

EXAMPLE:

FIGURE 32

E. Screw-pin anchor shackle

EXAMPLE:

FIGURE 33

F. Round-pin anchor shackle

EXAMPLE:

FIGURE 34

G. Safety-type anchor shackle

EXAMPLE:

FIGURE 35

H. Safety-type chain shackle

EXAMPLE:

FIGURE 36

I. Swivels

EXAMPLE:

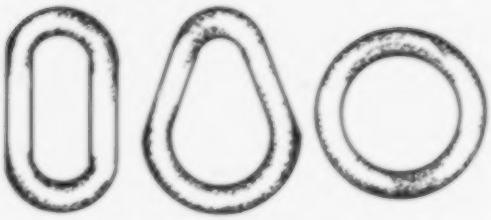
FIGURE 37

INFORMATION SHEET

J. Rings

EXAMPLE:

FIGURE 38



K. Standard houser thimble

EXAMPLE:

FIGURE 39

L. Swaged clevis fitting

EXAMPLE:

FIGURE 40

M. Drop-forged clip

EXAMPLE:

FIGURE 41

N. Open wedge socket

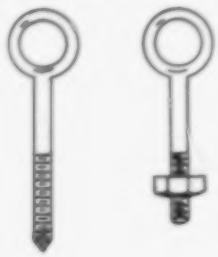
EXAMPLE:

FIGURE 42

O. Shoulderless eyebolts

EXAMPLE:

FIGURE 43

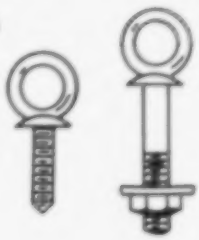


INFORMATION SHEET

P. Shouldered eyebolts

EXAMPLE:

FIGURE 44



Q. Standard choker hook

EXAMPLE:

FIGURE 45

R. Dual sliding-choker hook

EXAMPLE:

FIGURE 46

S. Jaw-and-eye turnbuckle

EXAMPLE:

FIGURE 47

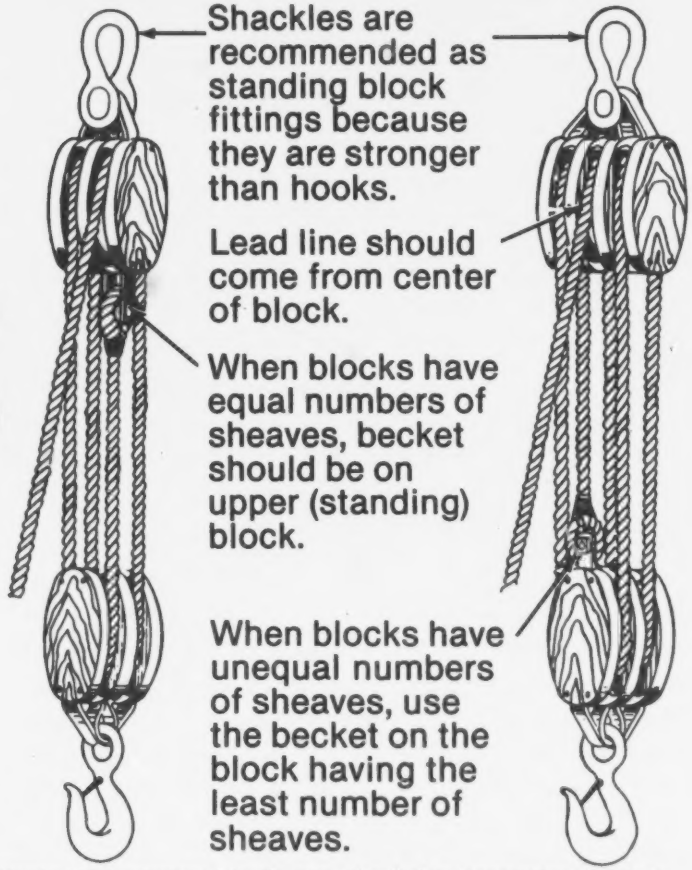
T. Hook-and-eye turnbuckle

EXAMPLE:

FIGURE 48

Block Reeving

Block Orientation in a Reeved System


Shackles are recommended as standing block fittings because they are stronger than hooks.
Lead line should come from center of block.
When blocks have equal numbers of sheaves, becket should be on upper (standing) block.
When blocks have unequal numbers of sheaves, use the becket on the block having the least number of sheaves.

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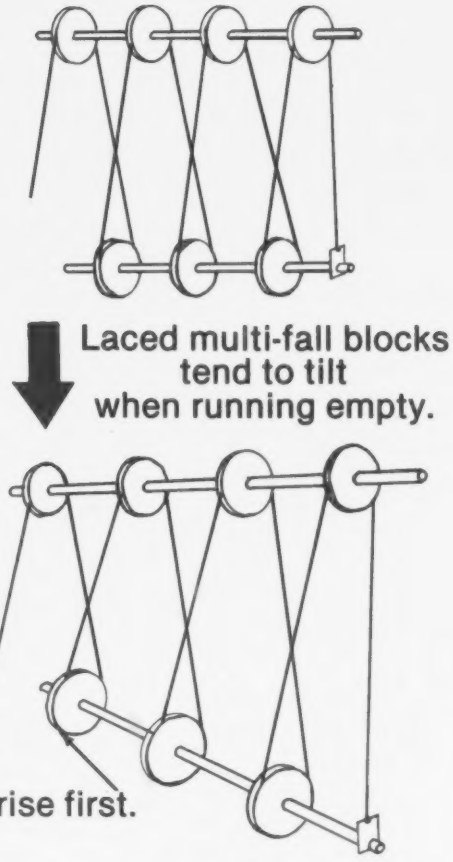
Effect of Lacing Rather Than Reeving Blocks



TM #1

HEM - 309-A

Parts of Line and Mechanical Advantage

One-Part Line
1:1

Two-Part Line
2:1

Three-Part Line
3:1

Seven-Part Line
7:1

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TM #2

HEM - 311-A

Factors to Account for Sheave Friction Loads

Friction Force = 10% of Sheave Load (Typical for Plain-Bore Sheaves and Poorly Maintained Bronze Bushing Sheaves)		
Number of Parts of Line (N)	Multiplication Factor (F)	Ratio (R) (R = N/F) = Actual Mechanical Advantage
1	1.10	.91
2	1.21	1.65
3	1.33	2.26
4	1.46	2.74
5	1.61	3.11
6	1.77	3.39
7	1.94	3.61
8	2.14	3.74
9	2.36	3.81
10	2.60	3.85
11	2.85	3.86
12	3.14	3.82
13	3.45	3.77
14	3.80	3.68
15	4.18	3.59
16	4.60	3.48
17	5.06	3.36
18	5.56	3.23
19	6.12	3.11
20	6.73	2.97

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Factors to Account for Sheave Friction Loads
(Continued)

Friction Force = 5% of Sheave Load (Typical for Bronze-Bushing Sheaves and Stiff Roller-Bearing Sheaves)		
Number of Parts of Line (N)	Multiplication Factor (F)	Ratio (R) (R = N/F) = Actual Mechanical Advantage
1	1.05	.95
2	1.10	1.82
3	1.16	2.59
4	1.22	3.28
5	1.28	3.91
6	1.34	4.48
7	1.41	4.96
8	1.48	5.41
9	1.55	5.81
10	1.63	6.13
11	1.71	6.43
12	1.80	6.67
13	1.89	6.88
14	1.98	7.07
15	2.08	7.21
16	2.18	7.34
17	2.29	7.42
18	2.41	7.47
19	2.53	7.51
20	2.65	7.55

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Factors to Account for Sheave Friction Loads
(Continued)

Friction Force = 3% of Sheave Load (Typical for Good Roller-Bearing Sheaves)		
Number of Parts of Line (N)	Multiplication Factor (F)	Ratio (R) (R = N/F) = Actual Mechanical Advantage
1	1.03	.97
2	1.06	1.89
3	1.09	2.75
4	1.13	3.54
5	1.16	4.31
6	1.20	5.00
7	1.23	5.69
8	1.27	6.30
9	1.31	6.87
10	1.35	7.41
11	1.39	7.91
12	1.43	8.39
13	1.47	8.84
14	1.51	9.27
15	1.56	9.62
16	1.61	9.94
17	1.65	10.30
18	1.70	10.59
19	1.76	10.80
20	1.81	11.05

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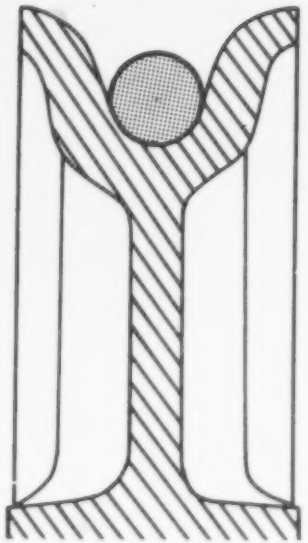
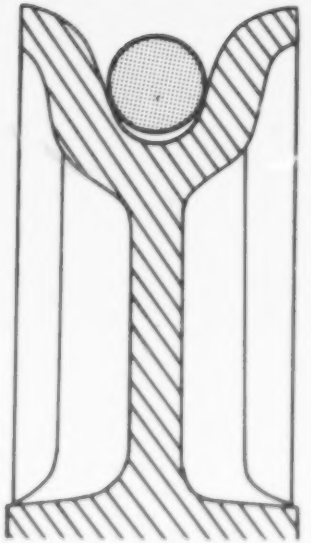
Matching Ropes and Sheaves

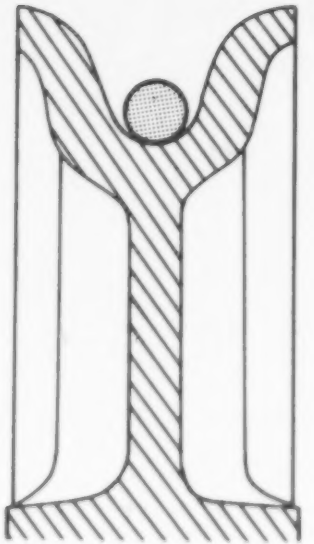
Properly Matched Rope and Sheave



Rope Too Large– Will Pinch



Rope Too Small– Will Flatten



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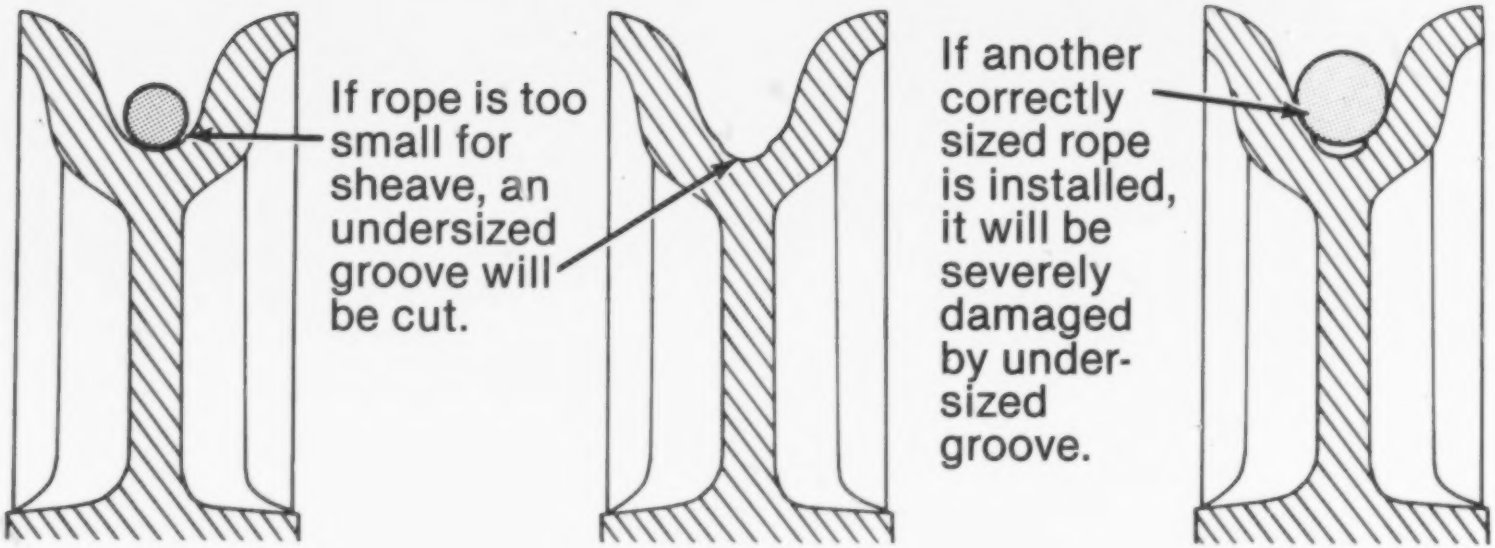
TM #6

HEM - 319-A

Effects of Improper Matching of Ropes and Sheaves


If rope is too small for sheave, an undersized groove will be cut.
If another correctly sized rope is installed, it will be severely damaged by under-sized groove.

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Safe Working Load (SWL) for Rope

Change Rope Diameter into Eighths of an Inch

SWL = Rope Diameter × Rope Diameter × Constant

Type of Rope	Diameter of Rope	Constant	SWL
Manila	3/8 Inch	20	180 Pounds
	1/2 Inch		320 Pounds
	5/8 Inch		500 Pounds
	3/4 Inch		720 Pounds
	7/8 Inch		980 Pounds
	1 Inch		1280 Pounds
Nylon	3/8 Inch	60	540 Pounds
	1/2 Inch		960 Pounds
	5/8 Inch		1500 Pounds
	3/4 Inch		2160 Pounds
	7/8 Inch		2940 Pounds
	1 Inch		3840 Pounds
Polyester	3/8 Inch	60	540 Pounds
	1/2 Inch		960 Pounds
	5/8 Inch		1500 Pounds
	3/4 Inch		2160 Pounds
	7/8 Inch		2940 Pounds
	1 Inch		3840 Pounds
Polypropylene	3/8 Inch	40	360 Pounds
	1/2 Inch		640 Pounds
	5/8 Inch		1000 Pounds
	3/4 Inch		1440 Pounds
	7/8 Inch		1960 Pounds
	1 Inch		2560 Pounds
Polyethylene	3/8 Inch	35	315 Pounds
	1/2 Inch		560 Pounds
	5/8 Inch		875 Pounds
	3/4 Inch		1260 Pounds
	7/8 Inch		1715 Pounds
	1 Inch		2240 Pounds

Safe Working Load (SWL) for Wire Rope

SWL = Rope Diameter x Rope Diameter x Constant

Type of Wire Rope	Diameter of Rope	Constant	SWL
	3/8 Inch	8	1.125 Tons
	1/2 Inch		2.0 Tons
	5/8 inch		3.125 Tons
	3/4 Inch		4.5 Tons
	7/8 Inch		6.12 Tons
	1 Inch		8.0 Tons
	1 1/8 Inch		10.125 Tons
	1 1/4 Inch		12.5 Tons
	1 3/8 Inch		15.125 Tons
	1 1/2 Inch		18.0 Tons

Formula for Calculating Sling Stress

$$\text{Stress} = \frac{\text{Weight of Load} \times \text{Length of Sling}}{\text{Height of Load} \times \text{Number of Sling Legs}}$$

EXAMPLES:

Where W = 10 Tons, L = 6 Feet, H = 4 Feet, N = 2

$$\frac{10 \times 6}{2 \times 4} = \frac{60}{8} = 8\overline{)60}\ \begin{matrix}7\,4/8\\ \\ 56\\ 4\end{matrix} = 7\ 1/2$$

Stress = 7 1/2 Tons Each Sling

Where W = 50 Tons, L = 12 Feet, H = 8 Feet, N = 3

$$\frac{50 \times 12}{8 \times 3} = \frac{600}{24} = 24\overline{)600}\ \begin{matrix}25\\ \\ 48\\ 120\\ 120\\ 0\end{matrix}$$

Stress = 25 Tons Each Sling

Where W = 100 Tons, L = 10 Feet, H = 2 Feet, N = 4

$$\frac{100 \times 10}{2 \times 4} = \frac{1000}{8} = 8\overline{)1000}\ \begin{matrix}125\\ \\ 8\\ 20\\ 16\\ 40\\ 40\\ 0\end{matrix}$$

Stress = 125 Tons Each Sling

Sling Angles and Load Factors

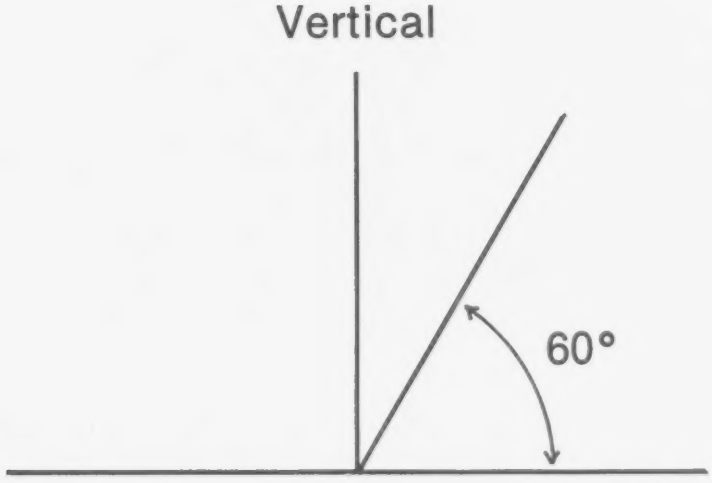
Sling Angles	Load Angle Factors
0°(Vertical)	1.000
15°	1.035
20°	1.064
25°	1.104
30°	1.155
35°	1.221
40°	1.305
45°	1.414
50°	1.555
55°	1.742
60°	2.000

Sling Angle

Critical Angle — Sling Angle That Exists When the Tension in the Sling Leg Equals the Weight of the Load

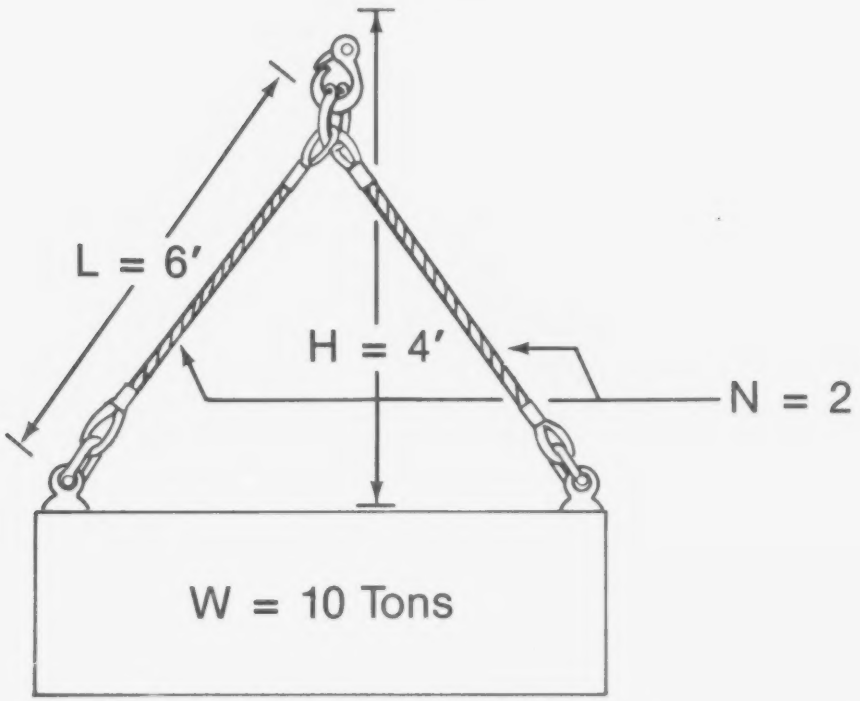
Critical Angle Formula

$$CA = \frac{60°}{N}$$



N = Number of Sling Legs

Formula for Calculating Sling Stress



$$S = \frac{W \times L}{H \times N}$$

$$S = \frac{10 \times 6}{2 \times 4}$$

$$S = \frac{60}{8}$$

$$S = 7\ 1/2 \text{ Tons}$$

BASIC RIGGING AND HOISTING
UNIT IV

ASSIGNMENT SHEET #1 — CALCULATE SAFE WORKING LOAD (SWL)
OF DIFFERENT TYPES AND SIZES OF ROPE

NAME _____ SCORE _____

Because it is difficult to remember safe working loads of common ropes, and because load tables may not always be available, it is important to know how to compute safe working load in pounds.

Calculate safe working load (SWL) of different types and sizes of rope. Use your Information Sheet for reference. Show your work.

Mathematical constants:

20 — Manila
35 — Polyethylene
40 — Polypropylene
60 — Nylon or polyester

EXAMPLE: $\frac{1}{2}$-inch manila rope = $\frac{4}{8}$-inch diameter

SWL = 4 x 4 x 20 = 320 pounds

PART I

A. 1-inch manila rope

SWL = _____

B. 1 1/2-inch manila rope

SWL = _____

C. 3/8-inch manila rope

SWL = _____

ASSIGNMENT SHEET #1

D. 1/4-inch polyester rope

SWL = _____

E. 1/2-inch polypropylene rope

SWL = _____

F. 1 7/8-inch polypropylene rope

SWL = _____

G. 1 3/8-inch polypropylene rope

SWL = _____

H. 5/8-inch polyester rope

SWL = _____

I. 1 1/4-inch nylon rope

SWL = _____

J. 1 1/8-inch polyethylene rope

SWL = _____

ASSIGNMENT SHEET #1

PART II

Use Tables 2 and 3 at the end of this assignment sheet to find safe working load (SWL) of different types and sizes of rope.

A. 1/2-inch polyester

SWL = _____

B. 3/4-inch polyethylene

SWL = _____

C. 3/8-inch manila

SWL = _____

D. 1-inch polypropylene

SWL = _____

E. 7/8-inch nylon

SWL = _____

F. 3/4-inch manila

SWL = _____

G. 3/8-inch polyester

SWL = _____

ASSIGNMENT SHEET #1

H. 5/8-inch nylon

SWL = _____

I. 1/2-inch polypropylene

SWL = _____

J. 1-inch polyethylene

SWL = _____

ASSIGNMENT SHEET #1

(NOTE: For immediate reference, cut out Tables 2 and 3, glue back to back, seal in a clear plastic, and keep with you.)

Table 2

Safe Working Load (SWL) for Rope

Change Rope Diameter into Eighths of an Inch

SWL = Rope Diameter x Rope Diameter x Constant

Type of Rope	Diameter of Rope	Constant	SWL
Manila	3/8 Inch	20	180 Pounds
	1/2 Inch		320 Pounds
	5/8 Inch		500 Pounds
	3/4 Inch		720 Pounds
	7/8 Inch		980 Pounds
	1 Inch		1280 Pounds
Nylon	3/8 Inch	60	540 Pounds
	1/2 Inch		960 Pounds
	5/8 Inch		1500 Pounds
	3/4 Inch		2160 Pounds
	7/8 Inch		2940 Pounds
	1 Inch		3840 Pounds
Polyester	3/8 Inch	60	540 Pounds
	1/2 Inch		960 Pounds
	5/8 Inch		1500 Pounds
	3/4 Inch		2160 Pounds
	7/8 Inch		2940 Pounds
	1 Inch		3840 Pounds
Polypropylene	3/8 Inch	40	360 Pounds
	1/2 Inch		640 Pounds
	5/8 Inch		1000 Pounds
	3/4 Inch		1440 Pounds
	7/8 Inch		1960 Pounds
	1 Inch		2560 Pounds
Polyethylene	3/8 Inch	35	315 Pounds
	1/2 Inch		560 Pounds
	5/8 Inch		875 Pounds
	3/4 Inch		1260 Pounds
	7/8 Inch		1715 Pounds
	1 Inch		2240 Pounds

Table 3

Safe Working Load (SWL) for Wire Rope

SWL = Rope Diameter x Rope Diameter x Constant

Type of Wire Rope	Diameter of Rope	Constant	SWL
	3/8 Inch	8	1.125 Tons
	1/2 Inch		2.0 Tons
	5/8 Inch		3.125 Tons
	3/4 Inch		4.5 Tons
	7/8 Inch		6.12 Tons
	1 Inch		8.0 Tons
	1 1/8 Inch		10.125 Tons
	1 1/4 Inch		12.5 Tons
	1 3/8 Inch		15.125 Tons
	1 1/2 Inch		18.0 Tons

Formula for Calculating Sling Stress

$$\text{Stress} = \frac{\text{Weight of Load} \times \text{Length of Sling}}{\text{Height of Load} \times \text{Number of Sling Legs}}$$

EXAMPLES:

Where W = 10 Tons, L = 6 Feet, H = 4 Feet, N = 2

$\frac{10 \times 6}{2 \times 4} = \frac{60}{8} = 8\overline{)60}^{7\frac{4}{8}}$ (56, 4) $= 7\frac{1}{2}$

Stress = 7 ½ Tons Each Sling

Where W = 50 Tons, L = 12 Feet, H = 8 Feet, N = 3

$\frac{50 \times 12}{8 \times 3} = \frac{600}{24} = 24\overline{)600}^{25}$ (48, 120, 120, 0)

Stress = 25 Tons Each Sling

Where W = 100 Tons, L = 10 Feet, H = 2 Feet, N = 4

$\frac{100 \times 10}{2 \times 4} = \frac{1000}{8} = 8\overline{)1000}^{125}$ (8, 20, 16, 40, 40, 0)

Stress = 125 Tons Each Sling

BASIC RIGGING AND HOISTING
UNIT IV

ASSIGNMENT SHEET #2 — CALCULATE SAFE WORKING LOAD (SWL) OF DIFFERENT SIZES OF WIRE ROPE

NAME _____ SCORE _____

Because it is difficult to remember safe working loads of common types of wire ropes, and because load tables may not always be available, it is important to know how to compute safe working load in tons.

Calculate safe working load (SWL) of different sizes of wire rope. Use your Information Sheet for reference. Round all answers to nearest whole number.

EXAMPLE: $\frac{1}{2}$-inch diameter wire rope

SWL $= \frac{1}{2} \times \frac{1}{2} \times 8 = 2$ tons

A. 5/8-inch diameter wire rope

SWL = _____

B. 7/8-inch diameter wire rope

SWL = _____

C. 1-inch diameter wire rope

SWL = _____

D. 1 1/8-inch diameter wire rope

SWL = _____

E. 1 1/2-inch diameter wire rope

SWL = _____

BASIC RIGGING AND HOISTING
UNIT IV

ASSIGNMENT SHEET #3 — CALCULATE SLING STRESS

NAME _____ SCORE _____

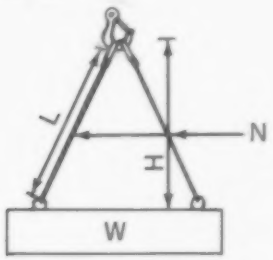
Heavy or continuous overloading should be avoided as well as sudden jerks that can build up momentary overload sufficient to break a sling; therefore, proper calculation of sling stress is essential for maximum service and safety.

Calculate sling stress for the following illustrations. Round your answers to the nearest one-quarter ton. Show your work.

EXAMPLE:

$$S = \frac{W \times L}{H \times N}$$

Where W = 10 tons
L = 3 feet
H = 2 feet
N = 2

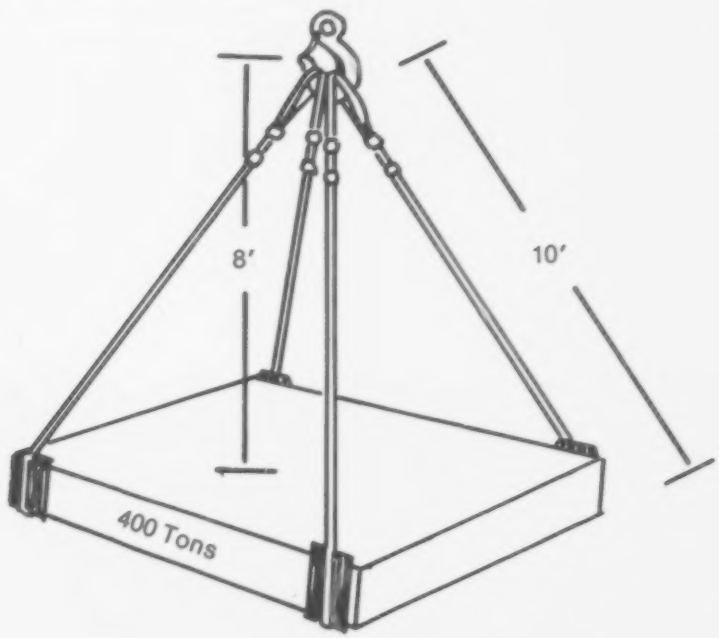


$$S = \frac{10 \times 3}{2 \times 2}$$

$$= \frac{30}{4}$$

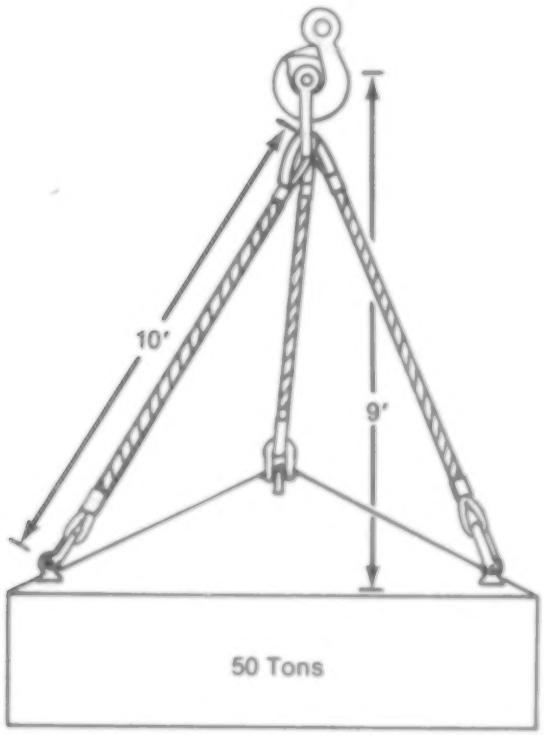
= 7½ tons each sling

A. Sling stress = _____



ASSIGNMENT SHEET #3

B. Sling stress = _____



BASIC RIGGING AND HOISTING
UNIT IV

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1

Part I		Part II	
A.	1,280 pounds	A.	960 pounds
B.	2,880 pounds	B.	1,260 pounds
C.	180 pounds	C.	180 pounds
D.	240 pounds	D.	2,560 pounds
E.	640 pounds	E.	2,940 pounds
F.	9,000 pounds	F.	720 pounds
G.	4,840 pounds	G.	540 pounds
H.	1,500 pounds	H.	1,500 pounds
I.	6,000 pounds	I.	640 pounds
J.	2,835 pounds	J.	2,240 pounds

Assignment Sheet #2

A. 3 tons

B. 6 tons

C. 8 tons

D. 10 tons

E. 18 tons

Assignment Sheet #3

A. 125 tons

B. 18 ½ tons

BASIC RIGGING AND HOISTING
UNIT IV

JOB SHEET #1 — INSTALL WIRE ROPE CLIPS

I. Equipment and materials

A. Length of wire rope

B. 3 clips

C. Thimble

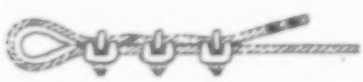
D. Wrench to fit nuts on clips

E. Torque wrench

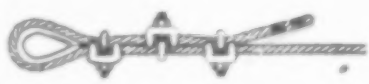
II. Procedure

A. Turn back a length of rope beyond pointed end of thimble equal to the number of clips times clip spacing (Figure 49; Table 4)

FIGURE 49



The Right Way to Clip Wire Rope



The Wrong Way to Clip Wire Rope

TABLE 4

NUMBER OF CLIPS AND SPACING FOR SAFE APPLICATION

Rope Diameter (inches)	Approximate Weight (pounds)	Minimum Number Clips for Each Rope End	Spacing of Clips (inches)
3/16	0.10	2	1 1/8
1/4	.19	2	1 1/2
5/16	.29	2	1 7/8
3/8	.47	2	2 1/4
7/16	.70	2	2 5/8
1/2	.78	3	3
5/8	1.06	3	3 3/4
3/4	1.59	4	4 1/2
7/8	2.40	4	5 1/4
1	2.72	4	6
1 1/8	3.20	5	6 3/4
1 1/4	4.50	5	7 1/2
1 3/8	4.60	6	8 1/4
1 1/2	5.80	6	9
1 5/8	7.20	6	9 3/4
1 3/4	9.50	7	10 1/2
2	12.50	8	12
2 1/4	15.50	8	13 1/2
2 1/2	18.00	8	15

(NOTE: Number and spacing of clips shown in table are minimum number required to develop 80 percent of full strength of the rope.)

Used with permission of W.G. (Bill) Newberry from *Handbook For Riggers*, rev. ed., 1977.

JOB SHEET #1

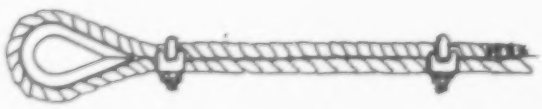
B. Position first clip at least one clip base width from end of wire rope (Figure 50)

FIGURE 50

C. Tighten nuts, alternating from one to the other to obtain equal clamping action

D. Position second clip next to end of thimble; tighten nuts until firm but not tight (Figure 51)

FIGURE 51



E. Space third clip equally between first two; tighten nuts until firm but not tight

F. Take up any rope slack; then alternately tighten nuts on each clip (Figure 52)

FIGURE 52

G. Torque all nuts to manufacturer's specifications

H. Clean and put away all tools and equipment

2.5
2.8
3.2
3.6
4.0
2.2
2.0
100 mm
1.0
1.1
1.25
1.4
1.6
1.8
1.0 mm
1.5 mm
2.0 mm
ABCDEFGHIJKLMNOPQRSTUVWXYZ
abcdefghijklmnopqrstuvwxyz1234567890
ABCDEFGHIJKLMNOPQRSTUVWXYZ
abcdefghijklmnopqrstuvwxyz
1234567890
A5

BASIC RIGGING AND HOISTING
UNIT IV

JOB SHEET #2 — RIG AND HANDLE DIFFERENT TYPES OF LOADS

I. Equipment

A. Hoist

B. Load

C. Slings

D. Spreader bar

II. Procedure for load where center of gravity is noncentered

(CAUTION: For loads that appear to be extremely heavy, the exact weight of the load must be determined prior to rigging to assure that the load will not exceed the lifting capacity of the hoist or the safe working load of the wire rope used.)

A. Estimate location of center of gravity

(NOTE: The load will always try to swing so that it is under the hook; this is the center of gravity.)

B. Spot hook over this point

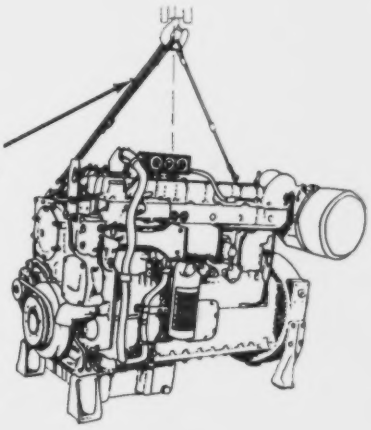
C. Attach slings of proper strength and length from hook to lifting lugs (Figure 53)

(NOTE: Slings of different length will probably have to be used. Because they are not always available, it may be necessary to improvise.)

(CAUTION: Be very careful that proper slings are used and that they are attached properly. Use wire rope clips if necessary.)

FIGURE 53

After adjusting sling to proper length, install a cable clip at this position.



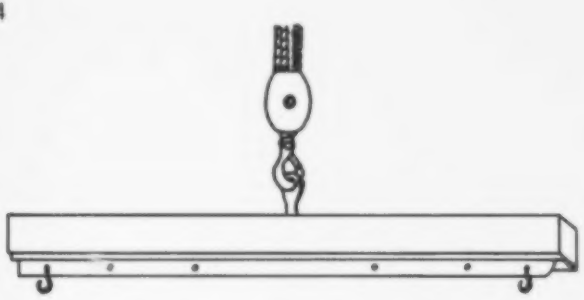
Source: Caterpillar Tractor Co.

JOB SHEET #2

III. Procedure for rigging extra long loads

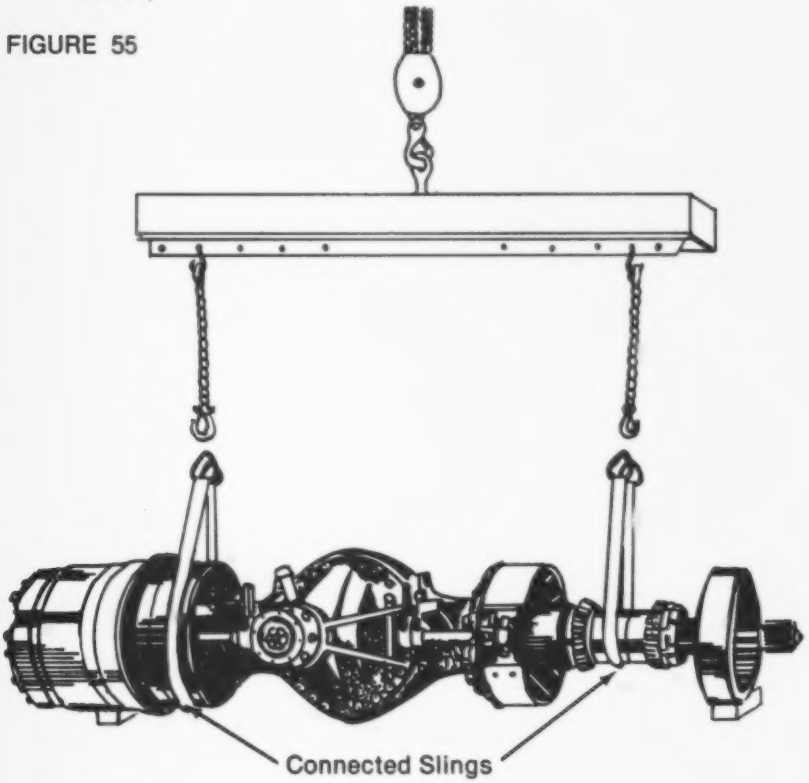
A. Attach spreader bar to hoist hook (Figure 54)

FIGURE 54



B. Center spreader bar over load; then connect sling to each end of load (Figure 55)

FIGURE 55

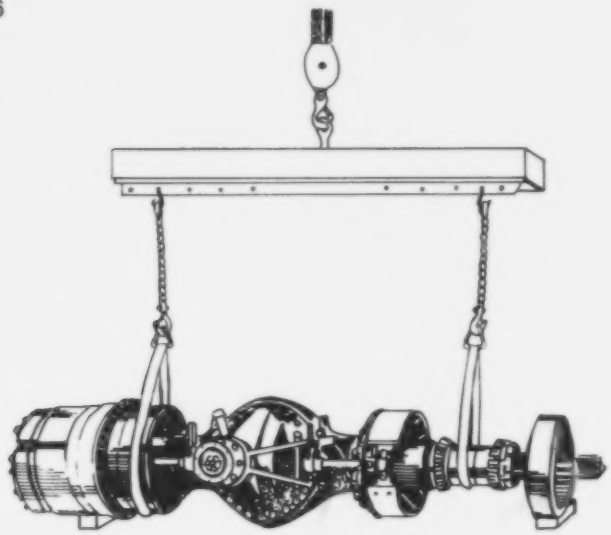


JOB SHEET #2

C. Connect long end of slings to spreader bar (Figure 56)

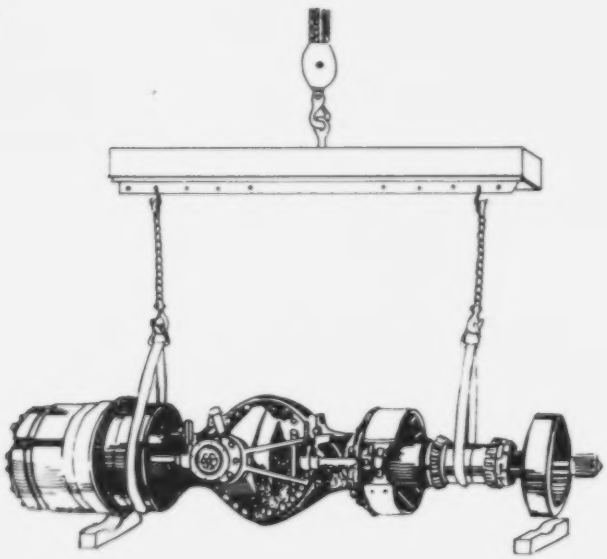
(NOTE: Be sure that hooks face out.)

FIGURE 56



D. Take up strain on line by lifting just a few inches to check balance of load (Figure 57)

FIGURE 57



E. Put away all tools and equipment

BASIC RIGGING AND HOISTING
UNIT IV

TEST

NAME _____ SCORE _____

1. Match to their correct definitions terms associated with rigging and hoisting. Write the correct numbers in the blanks. Definitions are continued on the next page.

_____a.	Setting up block and tackle to a winch; stacking and hoisting material and equipment, or replacing cables on equipment	1. Hitch
_____b.	Rope or cable with eyes spliced on each end, or an eye and hook; used to secure loads that are being hoisted	2. Block
_____c.	Rope used to guide or steady a load while it is being lifted	3. Sheave
_____d.	To attach a rope to a post, pole, ring, hook, or other object	4. Reeved blocks
_____e.	Assembly of blocks and lines used to gain a mechanical advantage in lifting	5. Rigging
_____f.	Grooved wheel or pulley	6. Splice
_____g.	To join two sections of rope or cable to form a continuous length	7. Mechanical advantage
_____h.	Connecting device for lines and drawbars; u-shaped and pierced for a cross bolt or pin	8. Thimble
_____i.	Part of line in block and tackle that is attached to block	9. Tagline
_____j.	Grooved metal ring inserted in loop of rope to prevent wear	10. Shackle
_____k.	One or more sheaves fitted in a frame supported by a hook or shackle inserted in the block strap	11. Tackle
_____l.	That point at which entire weight of a load may be concentrated so that if supported at this point the load would remain balanced	12. Choker
		13. Becket
		14. Center of gravity

TEST

_____m. Amount by which the machine multiples the force applied to it in order to lift or move a load

_____n. Two blocks attached with an attaching rope or cable that is laced through the sheaves on both blocks until all sheaves are used and end of rope or cable hangs loose as the lead line

2. State eight safety tips related to rigging and hoisting.

a. _____

_____

b. _____

_____

c. _____

_____

d. _____

_____

e. _____

_____

f. _____

_____

g. _____

_____

h. _____

_____

TEST

3. Label the types of hoisting devices illustrated below and on the following pages.

a. _____ b. _____ c. _____

_____ _____ _____

d. _____ e. _____

TEST

f. _____

_____

g. _____

_____

h. _____

_____

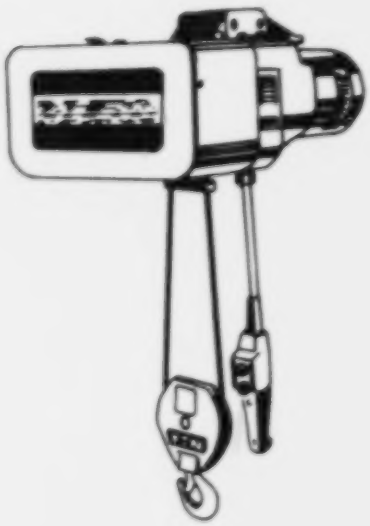
i. _____

_____

TEST

j. _____

k. _____



l. _____

m. _____

TEST

4. Select from the following list good rigging practices. Write an "X" in the blank before each correct answer.

_____a. Be sure to use shackles in eye splices

_____b. Be sure to use screw-pin shackle so that pin can roll under load

_____c. Secure all unused sling lines

_____d. Use shackles on chokers where there may be cutting action

_____e. Turn hooks down

_____f. Always use eyebolts when lifting at an angle

_____g. Be sure that rope is wrapped around hook

_____h. Use tagline to control load

_____i. Never allow a shackle to be pulled at an angle

_____j. Center lifting device over load before lifting

_____k. Use shackles whenever two or more ropes are to be used over a hook

_____l. Be sure that span is greater than length of sling for proper sling angle

_____m. Do not permit bending of rope near a splice or attached fitting

5. State effects of lacing rather than reeving blocks.

a. _____

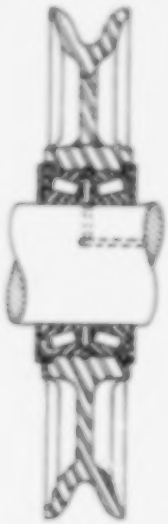
b. _____

c. _____

TEST

6. Identify the sheave bearing configurations illustrated below and on the next page. Write the correct names in the blanks.

Plain-bore sheave
Roller/thrust-bearing sheave
Roller-bearing sheave
Pressure-lubricated bronze-bearing sheave
Roller-bushed sheave



a. _____ b. _____ c. _____

_____ _____ _____

TEST

d. _____ e. _____

_____ _____

7. List four factors involved in selecting blocks and reeving for a particular application.

a. _____

b. _____

c. _____

d. _____

8. Discuss the mechanical advantage of any multiple-part reeved system.

_____

_____

_____

9. Define *sheave friction*.

_____

_____

TEST

10. Name minimum and maximum sheave groove tolerances for specific rope diameters. Write the correct tolerances in the blanks.

Rope Diameters	Minimum	Maximum
1/4 to 9/16-inch	a. _____	e. _____
5/8 to 7/8-inch	b. _____	1/16-inch
15/16 to 1 1/8-inch	3/64-inch	f. _____
1 3/16 to 1 1/2-inch	c. _____	g. _____
1 9/16 to 2 1/4-inch	d. _____	3/32-inch
2 5/16-inch and up	1/8-inch	h. _____

11. Calculate safe working load (SWL) of the following different types and sizes of ropes. Show your work.

a. 3/4-inch manila rope

(Mathematical constant is 20.)

SWL = _____

b. 3/4-inch nylon rope

(Mathematical constant is 60.)

SWL = _____

c. 3/8-inch polyester rope

(Mathematical constant is 60.)

SWL = _____

d. 3/8-inch polyethylene rope

(Mathematical constant is 35.)

SWL = _____

TEST

e. 1 1/8-inch polypropylene rope

(Mathematical constant is 40.)

SWL = _____

12. Calculate safe working load (SWL) of the following different sizes of wire ropes. Show your work.

a. 3/8-inch diameter wire rope

SWL = _____

b. 3/4-inch diameter wire rope

SWL = _____

c. 1-inch diameter wire rope

SWL = _____

d. 1 1/4-inch diameter wire rope

SWL = _____

e. 1 3/8-inch diameter wire rope

SWL = _____

13. State the importance of spreading angles.

a. _____

_____

b. _____

_____

c. _____

_____

d. _____

_____

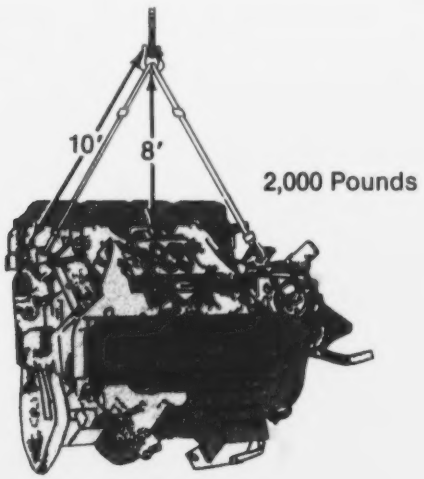
e. _____

_____

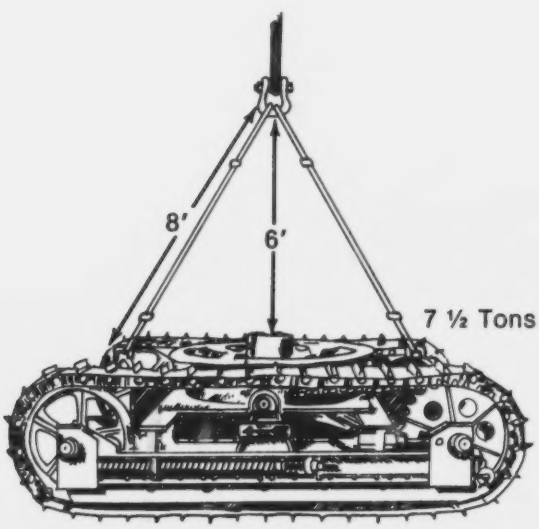
TEST

14. Calculate sling stress for the rigging shown in the following illustrations. Write the correct answers in the blanks.

a. Stress = _____ each sling



b. Stress = _____ each sling



TEST

15. Arrange in order steps to take when performing maintenance on wire rope. Write a "1" before the first step, a "2" before the second step, and so on.

_____a. Let rope cool so that oil thickens

_____b. Apply oil by moving rope through a long pan filled with oil

_____c. Check for frayed or worn wires

_____d. Wipe off surplus oil as rope leaves pan

_____e. Heat oil recommended by manufacturer

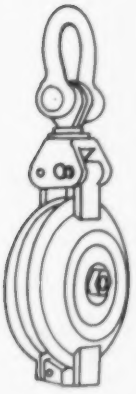
16. Identify types of snatch blocks. Write the correct names in the blanks. Snatch blocks are continued on the next page.

Upset swivel shackle
Swivel shackle
Self-locking
Swivel hook
Drop link
Swivel eye

a. _____ b. _____

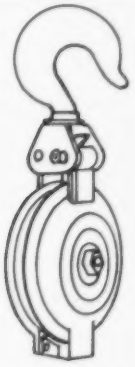
TEST

c. _____



d. _____

e. _____



f. _____

17. Select from the following list types of rigging hardware. Write an "X" in the blank before each correct answer.

_____a. Drop-forged clip

_____b. Deep socket

_____c. Hook-and-eye turnbuckle

_____d. Chain slip hook

_____e. Safety-type screw anchors

_____f. Swivels

_____g. Shouldered eyebolts

_____h. Dual sliding-choker hook

TEST

_____i. Hook adapter

_____j. Safety hook

_____k. Round-pin anchor shackle

_____l. Adjusting hook

_____m. Jaw-and-eye turnbuckle

_____n. Grab hook

_____o. Swivel adapter

_____p. Swaged clevis fitting

_____q. Safety-type anchor shackle

_____r. Standard choker hook

_____s. Slip hook

_____t. Arm wedge

_____u. Safety-type chain shackle

_____v. Open wedge socket

(NOTE: Test question 18 lists the job sheets. They are an important part of this test. If they have not been completed, check with your instructor.)

18. Demonstrate the ability to

a. Install wire rope clips.

b. Rig and handle different types of loads.

BASIC RIGGING AND HOISTING
UNIT IV

ANSWERS TO TEST

1.	a.	5	f.	3	k.	2
	b.	12	g.	6	l.	14
	c.	9	h.	10	m.	7
	d.	1	i.	13	n.	4
	e.	11	j.	8		

2. Answer should include any eight of the following

   a. Use personal protective devices such as goggles, gloves, safety shoes, and hard hat

   b. Use tagline to guide or steady load

   c. Do not walk under load

   d. Be sure that load is balanced properly

   e. Do not overload hoist, chokers, or slings

   f. Lubricate slings and cables to prevent rust

   g. Be sure that all hooks have safety snaps

   h. Know your equipment's maximum operating capacity

   i. Know and respond to hand signals

   j. Be sure that all safety devices function properly

   k. Operate hoist controls smoothly

   l. Be sure that all safety guards are in their proper places

   m. Keep equipment clean and in good working order

   n. Test load for proper rigging before actually lifting it

   o. Inspect chains and cables regularly

ANSWERS TO TEST

3. a. Pedestal-type hand winch
   b. Chain lever hoist
   c. Simple block and tackle
   d. Mobile hydraulic shop crane
   e. Typical screw-geared chain hoist
   f. Electric chain hoist
   g. Portable gantry crane
   h. Cable lever unit (winch hoist)
   i. Typical differential-type chain hoist
   j. Truck-mounted hydraulic crane
   k. Hand chain hoist
   l. Electric cable hoist
   m. Typical spur-geared chain hoist

4. c, d, h, i, j, k, m

5. a. Tendency to tilt when running empty
   b. Excessive wear
   c. Damage to sheaves and rope

6. a. Roller-bearing sheave
   b. Roller-bushed sheave
   c. Roller/thrust-bearing sheave
   d. Plain-bore sheave
   e. Pressure-lubricated, bronze-bearing sheave

ANSWERS TO TEST

7. Answer should include any four of the following
   a. Working load
   b. Connections
   c. Sheaves
   d. Pins
   e. Structural details
   f. Mechanical advantage required

8. Discussion should include the following — is always equal to the number of parts of line supporting the running block and the load, excluding lead line

9. Definition should include the following — Loss or decrease in mechanical advantage as rope passes over sheaves

10.
   a. 1/64-inch
   b. 1/32-inch
   c. 1/16-inch
   d. 3/32-inch
   e. 1/32-inch
   f. 3/32-inch
   g. 1/8-inch
   h. 1/4-inch

11.
   a. 720 pounds
   b. 2,160 pounds
   c. 540 pounds
   d. 315 pounds
   e. 3,240 pounds

12.
   a. 1 1/8 tons
   b. 4 1/2 tons
   c. 8 tons
   d. 12 1/2 tons
   e. 15 1/8 tons

ANSWERS TO TEST

13. a. Changing angle of sling leg may increase stress on sling

    b. As the angle is reduced, lifting capacity is reduced very rapidly

    c. When single leg of sling is at 60-degree angle, lifting capacity is only 87 percent of that of a vertical leg

    d. When single leg of sling is at 45-degree angle, lifting capacity is only 71 percent of that of a vertical leg

    e. When single leg of sling is at a 30-degree angle, lifting capacity is only 50 percent of that of a vertical leg

14. a. 5/8 ton

    b. 5 tons

15. a. 5

    b. 3

    c. 1

    d. 4

    e. 2

16. a. Self-locking

    b. Upset swivel shackle

    c. Drop link

    d. Swivel shackle

    e. Swivel eye

    f. Swivel hook

17. a, c, d, f, g, h, j, k, m, n, p, q, r, s, u, v

18. Performance skills evaluated to the satisfaction of the instructor

BASIC ENGINE PRINCIPLES
UNIT I

UNIT OBJECTIVE

After completing this unit, the student should be able to explain engine operation; calculate work, horsepower, torque, and displacement; and identify engine components. The student will show this knowledge by completing assignment sheets and unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match to their correct definitions terms associated with basic engine principles.
2. Discuss characteristics of energy.
3. List types of energy.
4. Distinguish between potential and kinetic energy, the forms of available energy.
5. Identify types of motion.
6. Identify types of simple machines.
7. List uses of simple machines.
8. Calculate problems, using the formula for work.
9. Calculate problems, using the formula for horsepower.
10. Calculate problems, using the formula for torque.
11. State the function of heat engines.
12. Name types of heat engines.
13. Match the parts of a basic internal-combustion engine to their correct descriptions.
14. Describe the process by which a gasoline engine converts chemical energy to rotary motion.
15. Distinguish among operations of a four-stroke-cycle engine.
16. Discuss specific valve timing and valve overlap.

OBJECTIVE SHEET

17. Discuss operation of a two-stroke-cycle engine.

18. State the formula for calculating engine cubic-inch displacement.

19. State the results of increasing compression ratio.

20. Distinguish between characteristics of gasoline engines and characteristics of diesel engines.

21. Identify basic parts of a gasoline engine.

22. Identify basic parts of a diesel engine.

23. State the purposes of a heavy flywheel.

BASIC ENGINE PRINCIPLES
UNIT I

SUGGESTED ACTIVITIES

I. Suggested activities

A. Order materials to supplement unit.

(NOTE: Engine manufacturers are excellent sources for slide and film presentations on gasoline and diesel engines. Write directly to the appropriate company or manufacturer.)

B. Check with major engine manufacturers for visual aids to demonstrate basic engine operation.

C. Obtain transparencies.

(NOTE: Transparencies are available from AGC and CIMC.)

D. Provide students with objective sheet.

E. Discuss unit and specific objectives.

F. Provide students with information and assignment sheets.

G. Discuss information and assignment sheets.

H. Give test.

I. Complete appropriate section of competency profiles.

(NOTE: Competency profiles are available from AGC and CIMC.)

II. Instructional materials

A. Objective sheet

B. Suggested activities

C. Information sheet

D. Transparency masters

1. TM #1 — Parts of a Basic Internal-Combustion Engine

2. TM #2 — Process by Which a Gasoline Engine Converts Chemical Energy to Rotary Motion

3. TM #3 — Four-Stroke-Cycle Gasoline Engine

SUGGESTED ACTIVITIES

4. TM #4 — Four-Stroke-Cycle Diesel Engine
5. TM #5 — Valve Timing and Valve Overlap
6. TM #6 — Two-Stroke-Cycle Gasoline Engine
7. TM #7 — Two-Stroke-Cycle Diesel Engine

E. Assignment sheets

1. Assignment Sheet #1 — Calculate Work
2. Assignment Sheet #2 — Calculate Horsepower
3. Assignment Sheet #3 — Calculate Torque
4. Assignment Sheet #4 — Calculate Cubic-Inch Displacement

F. Answers to assignment sheets

G. Test

H. Answers to test

III. Unit references

A. Armstrong, Ivan J. *Auto Mechanics, Vol. I.* Stillwater, Oklahoma: State Department of Vocational and Technical Education/Curriculum and Instructional Materials Center, 1976.

B. Armstrong, Ivan J. *Auto Mechanics, Vol. II.* Stillwater, Oklahoma: State Department of Vocational and Technical Education/Curriculum and Instructional Materials Center, 1978.

BASIC ENGINE PRINCIPLES
UNIT I

INFORMATION SHEET

I. Terms and definitions

A. BDC — Bottom dead center

B. Bore — Diameter of cylinder

C. CID — Cubic-inch displacement

(NOTE: Metric measurement for displacement is in cubic centimeters or liters.)

D. Control — To exercise restraining or directing influences over working forces

E. Cycle — Series of events or operations that happens regularly and leads back to starting point

F. Detonation — Rapid combustion in an internal-combustion engine; results in knocking

G. Displacement — Total volume of air/fuel compressed by the piston in traveling from BDC to TDC

H. Energy — Ability to do work

I. Flywheel — Mechanism that attaches to end of crankshaft and provides inertia to carry crankshaft around from one firing impulse to the other

J. Force — Any agent that produces or tends to produce motion

K. Friction — Resistance to relative motion between two bodies in contact

L. Horsepower (hp) — Measurement of work accomplished in a given period of time

M. Kinetic energy — Energy in motion

N. Mechanical power — Transmission and control of motion through use of gears, pulleys, shafts, and other mechanical devices

O. Potential energy — Stored energy

P. Power — Rate at which work is done

INFORMATION SHEET

Q. psi — Pounds per square inch; most common unit for measuring pressure

(NOTE: The metric equivalent of pounds per square inch is kilograms per square centimeter [kg/cm^2].)

R. Reciprocating motion — Back-and-forth motion

S. Stroke — Distance piston moves when traveling from TDC to BDC

T. TDC — Top dead center

U. Torque (T) — Measurement of turning or twisting power

V. Transmission — Relay of working force

W. Work — Result of force overcoming a resistance over a definite distance

II. Characteristics of energy

A. Is ever present

B. Cannot be created or destroyed

C. Can only be changed from one kind of energy to another

III. Types of energy

A. Light

B. Heat

C. Chemical

D. Electrical

E. Nuclear

F. Mechanical

IV. Forms of available energy

A. Potential — Stored energy, such as fuel and coal

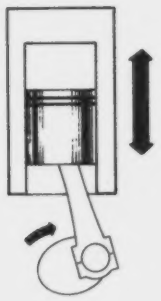
B. Kinetic — Energy in motion, such as wind, water, and burning gasoline

INFORMATION SHEET

V. Types of motion (Figures 1-3)

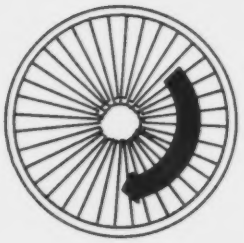
A. Reciprocating

FIGURE 1



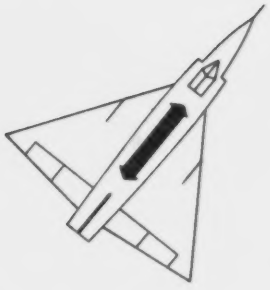
B. Rotary

FIGURE 2



C. Linear

FIGURE 3



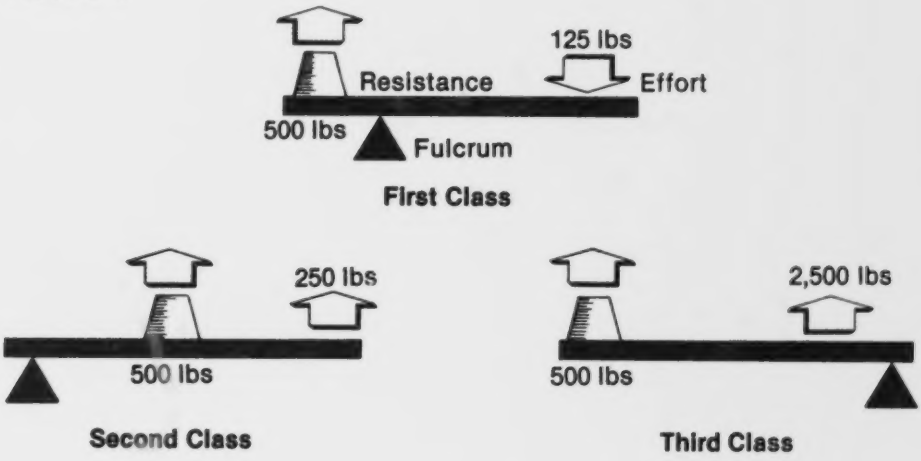
INFORMATION SHEET

VI. Types of simple machines (Figures 4-9)

(NOTE: All of the complicated mechanisms used to operate, manufacture, and repair an engine are combinations of six simple machines.)

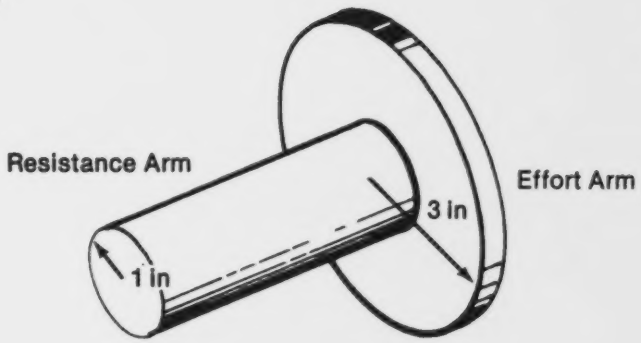
A. Lever

FIGURE 4



B. Wheel and axle

FIGURE 5

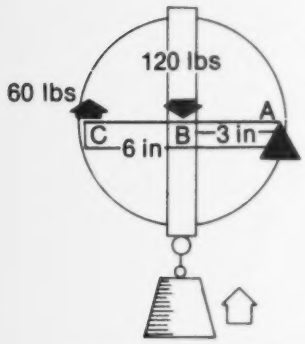


The mechanical advantage of the wheel and axle is the ratio between the two lever arms, 3 to 1.

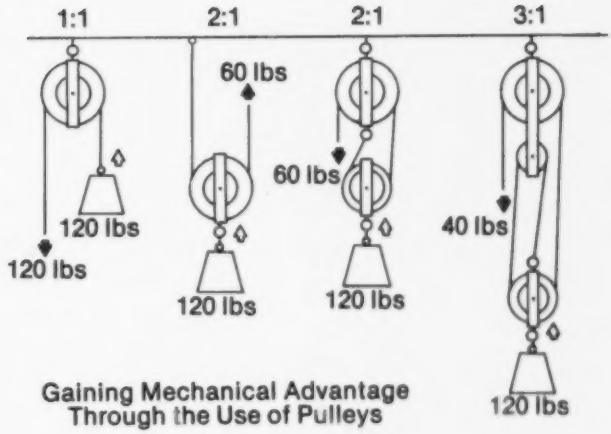
INFORMATION SHEET

C. Pulley

FIGURE 6



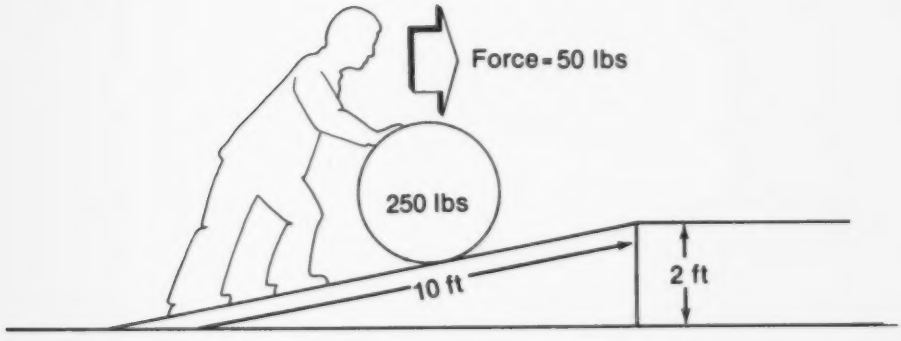
The pulley operates as a second-class lever.



Gaining Mechanical Advantage Through the Use of Pulleys

D. Inclined plane

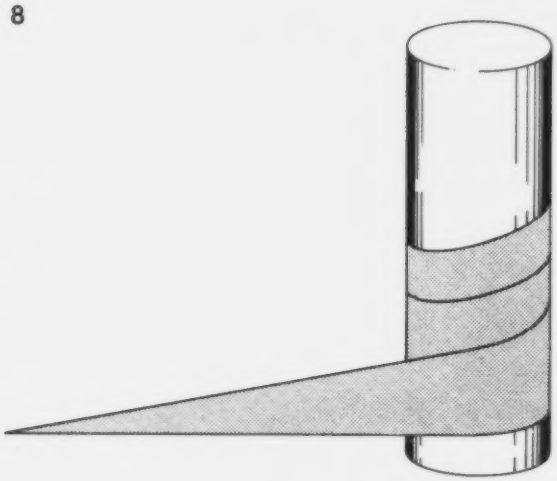
FIGURE 7



INFORMATION SHEET

E. Screw

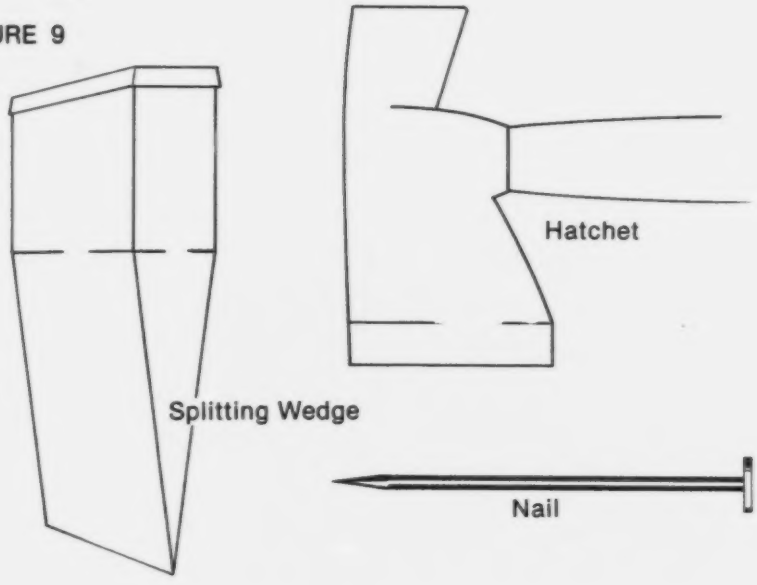
FIGURE 8



The screw is illustrated by an inclined plane wrapped around a shaft.

F. Wedge

FIGURE 9



INFORMATION SHEET

VII. Uses of simple machines

A. Increasing force

B. Changing direction

C. Changing speed

VIII. Calculating work (Assignment Sheet #1) — Use the formula

$$\text{Work (W)} = \text{Force (F)} \times \text{Distance (D)}.$$

(NOTE: Force must be used to measure work for all movement except lifting. Work is measured in foot-pounds.)

EXAMPLE: How much work is accomplished if it takes 80 pounds of force to move a 300-pound engine 50 feet?

$$W = F \times D$$

$$= 80 \times 50$$

$$= 4{,}000 \text{ foot-pounds}$$

IX. Calculating horsepower (Assignment Sheet #2) — Use the formula

$$\text{Horsepower (hp)} = \frac{\text{Force (F)} \times \text{Distance (D)}}{\text{Time (Sec)} \times 550}$$

or

$$= \frac{\text{Weight (W)} \times \text{Distance (D)}}{\text{Time (Sec)} \times 550}.$$

(NOTE: One horsepower is 550 foot-pounds of work done in one second. Force must be used instead of weight in all situations except lifting.)

EXAMPLE: A 180-pound man climbs a 10-foot flight of stairs in 5 seconds. How much horsepower does he develop?

$$hp = \frac{W \times D}{\text{Time (Sec)} \times 550}$$

$$= \frac{180 \times 10}{5 \times 550}$$

$$= \frac{1800}{2750}$$

$$= 0.65$$

INFORMATION SHEET

X. Calculating torque (Assignment Sheet #3) — Use the formula

Torque (T) = Force (F) × Radius (R).

(NOTE: Unit of measurement is foot-pounds, measured as a force applied to a radius.)

EXAMPLE: If a force of 25 pounds is applied to a wrench 2 feet long, what is the torque?

$T = F \times R$

$= 25 \times 2$

= 50 foot-pounds

XI. Function of heat engines — To convert heat energy into usable power in the form of motion

XII. Types of heat engines

A. External combustion — Fuel produces heat energy outside the engine; heat is transmitted to engine by water or other means; engine converts heat energy to motion

EXAMPLE: Steam

B. Internal combustion — Fuel produces heat energy inside the engine; engine converts heat energy to motion

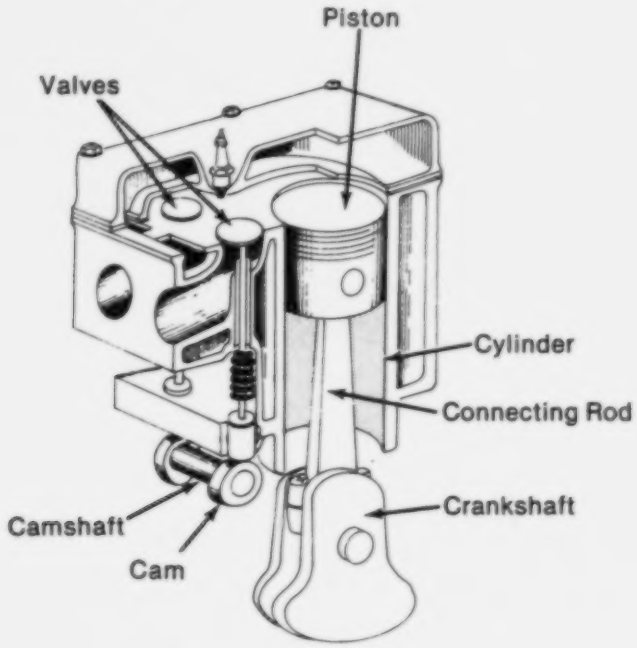
EXAMPLES: Gasoline, diesel

INFORMATION SHEET

XIII. Parts of a basic internal-combustion engine and their descriptions (Figure 10; Transparency #1)

EXAMPLE:

FIGURE 10



A. Cylinder — Hollow tube closed at one end

B. Piston — Cylindrical object that slides within the tube (cylinder), fitting tightly to seal other end of tube

C. Connecting rod — Straight rod with one end connected to a pivot in the piston so that lower end can swing with the rotation of crankshaft

D. Crankshaft — Main shaft of an engine, which, in conjunction with connecting rods, changes reciprocating motion of piston into rotary motion

(NOTE: Lower end of connecting rod is connected to offset-center portion of crankshaft and must follow the same circular path as shaft.)

E. Valve — Movable plug to open and close the cylinder in order to let in air/fuel mixture (intake valve) and to remove the burned fuel from cylinder (exhaust valve)

INFORMATION SHEET

F. Camshaft — Shaft on which cams (lobes) and bearing journals are located; usually used to open the valves

XIV. Process by which a gasoline engine converts chemical energy to rotary motion (Transparency #2)

A. Gasoline and air are introduced into upper end of cylinder

B. Air/fuel mixture is ignited and burned, producing heat energy

C. Heat energy causes cylinder gases to expand

D. Expansion of the burning gases pushes piston down cylinder

E. Downward motion of piston transmits force to crankshaft through connecting rod, thus producing rotary motion

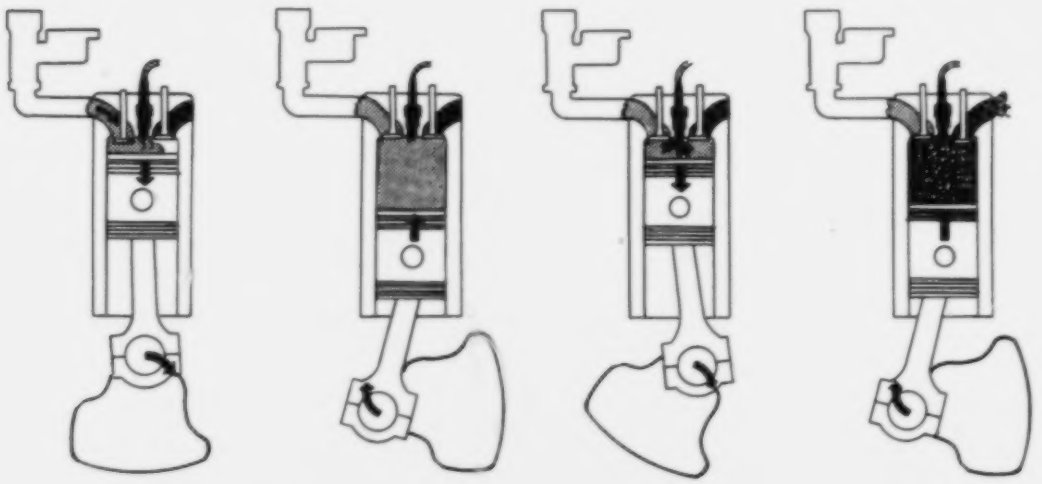
(NOTE: Rotary motion is the result of the turning crankshaft.)

XV. Operations of a four-stroke-cycle engine (Figures 11 and 12; Transparencies #3 and #4)

(NOTE: *Four-stroke* refers to the number of times the piston travels up and down in the cylinder to complete one cycle of operation.)

EXAMPLE: Gasoline

FIGURE 11

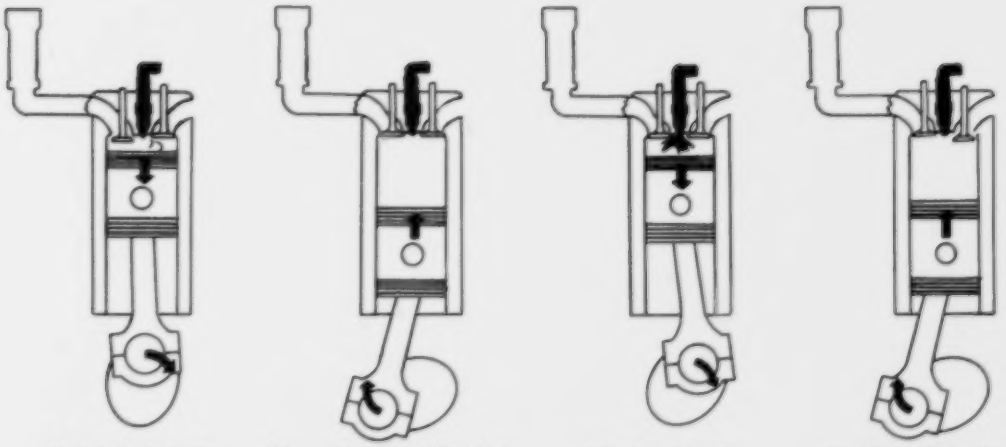


Intake Stroke **Compression Stroke** **Power Stroke** **Exhaust Stroke**

INFORMATION SHEET

EXAMPLE: Diesel

FIGURE 12



A. Intake stroke

1. Piston is at topmost position (TDC), with intake valve open and exhaust valve closed
2. As piston moves down the cylinder, it draws air/fuel mixture into cylinder from carburetor
3. When piston reaches bottom of cylinder (BDC), the intake valve closes, completing stroke

B. Compression stroke

1. Air/fuel mixture is compressed tightly as piston moves up the cylinder
2. Compression of fuel creates heat, which prepares the fuel for instant ignition

C. Power stroke

1. As piston reaches top of cylinder on compression stroke, a spark from the ignition system ignites the air/fuel mixture
2. The burning gases expand very rapidly and force the piston down the cylinder

INFORMATION SHEET

D. Exhaust stroke

1. As piston reaches bottom of cylinder on power stroke, the exhaust valve opens

2. Piston travels up the cylinder, forcing burned gases out of cylinder and into exhaust manifold

(NOTE: The complete cycle takes two rotations of the crankshaft or 720 degrees of rotation.)

XVI. Specific valve timing and valve overlap (Transparency #5)

(NOTE: Valve angles given below are approximate; actual angles will vary widely depending upon the engine design.)

A. Intake valve — Opens approximately 15 degrees before intake stroke begins; remains open through intake stroke and 20 degrees into compression stroke

(NOTE: The intake valve is open approximately 235 degrees of the 720-degree cycle.)

B. Exhaust valve — Opens approximately 40 degrees before exhaust stroke begins; remains open through exhaust stroke and 20 degrees into intake stroke

(NOTE: The exhaust valve is open approximately 235 degrees of the 720-degree cycle.)

C. Valve overlap — Both intake and exhaust valves partially open; intake valve starts to open before exhaust valve is closed

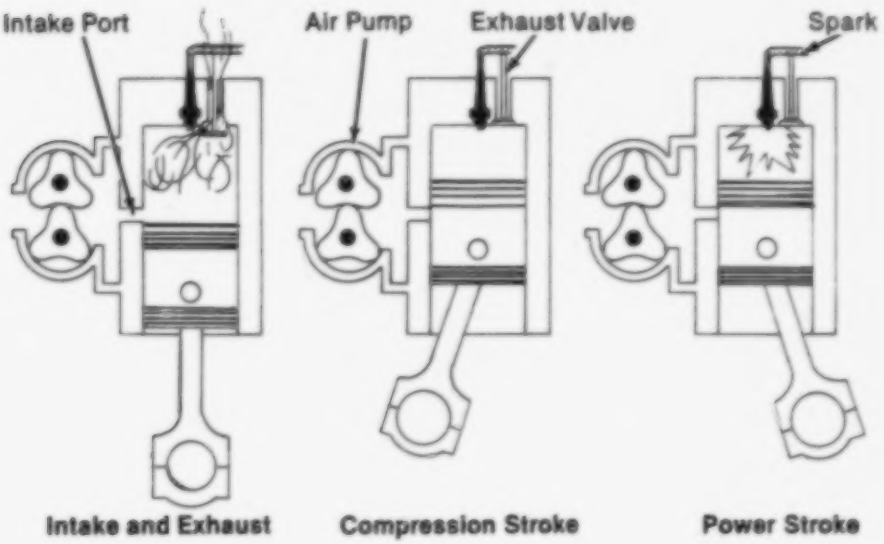
INFORMATION SHEET

XVII. Operation of a two-stroke-cycle engine (Figures 13 and 14; Transparencies #6 and #7)

(NOTE: The two-stroke cycle is best explained by starting with the piston at the bottom of the cylinder.)

EXAMPLE: Gasoline

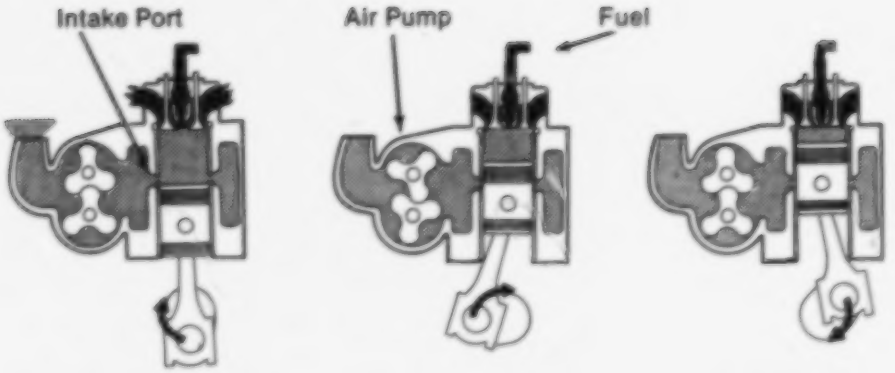
FIGURE 13



INFORMATION SHEET

EXAMPLE: Diesel

FIGURE 14



A. Air/fuel mixture is introduced into cylinder when piston is at the bottom

(NOTE: Fuel is pressured into the cylinder by a blower or by crankcase pressure.)

B. Pressure moves up the cylinder, compressing the mixture

C. Air/fuel mixture is ignited as piston reaches TDC

(NOTE: The crankshaft has moved a half revolution, or 180 degrees.)

D. Expanding gases push piston down the cylinder, forcing crankshaft to rotate

E. As piston reaches bottom of cylinder again, burned gases are allowed to escape through one side of cylinder or exhaust valve as a fresh charge of air and fuel is introduced into the other side

(NOTE: The crankshaft has now rotated one complete revolution, or 360 degrees.)

INFORMATION SHEET

XVIII. Calculating engine cubic-inch displacement (Figure 15; Assignment Sheet #4) — Use the formula

$$\text{Cubic-Inch Displacement (CID)} = \frac{\pi \times \text{Bore}^2 \times \text{Stroke}}{4} \times \text{Number of Cylinders}$$

EXAMPLE: An 8-cylinder engine with a 4-inch bore and a 3 ½-inch stroke has how much displacement?

$$\text{CID} = \frac{3.1416 \times \text{Bore}^2 \times \text{Stroke}}{4} \times \text{Number of Cylinders}$$

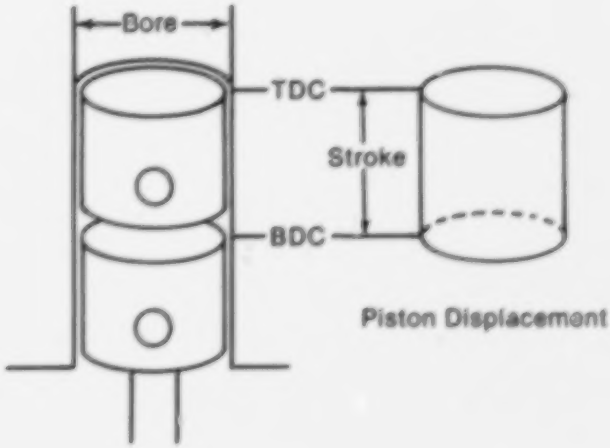
$$= \frac{3.1416 \times 4^2 \times 3.5}{4} \times 8$$

$$= 43.98 \times 8$$

$$= 351.86 \text{ cubic inches}$$

(NOTE: 61.02 cubic inches equals 1 liter.)

FIGURE 15

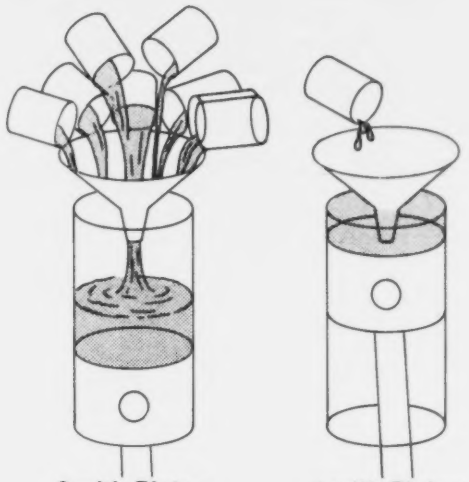


INFORMATION SHEET

XIX. Results of increasing compression ratio (Figure 16)

EXAMPLE:

FIGURE 16



A. Power increases as compression ratio increases

B. Fuel economy increases as compression ratio increases

(NOTE: The highest ratio that is practical for a gasoline engine is in the range of 10:1 to 12:1.)

C. As compression ratio is increased, higher-octane fuel is required to prevent engine knock due to detonation

D. Higher compression ratios produce more exhaust-gas pollutants

XX. Characteristics of gasoline and diesel engines

A. Gasoline

1. Is ignited by electrical spark
2. Takes fresh air and fuel through carburetor and intake manifold, and then into combustion chamber
3. Has low compression ratio (7:1 to 12:1)
4. Burns gasoline
5. Delivers fuel by air/fuel mixture drawn through carburetor and intake manifold into combustion chamber

INFORMATION SHEET

B. Diesel

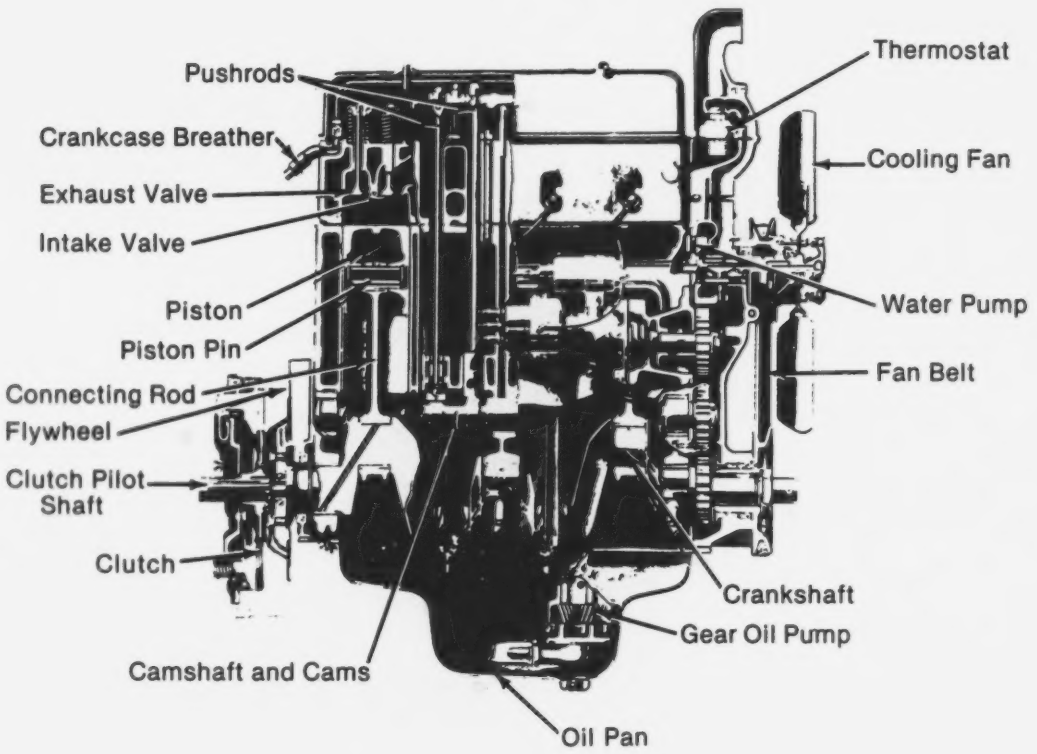
1. Is ignited by compression

   (NOTE: Fuel is ignited by the heat from compression.)

2. Takes fresh air directly into combustion chamber
3. Has high compression ratio (16:1 to 22:1)
4. Burns low-grade fuel oil
5. Injects fuel directly into combustion chamber

XXI. Basic parts of a gasoline engine (Figure 17)

FIGURE 17

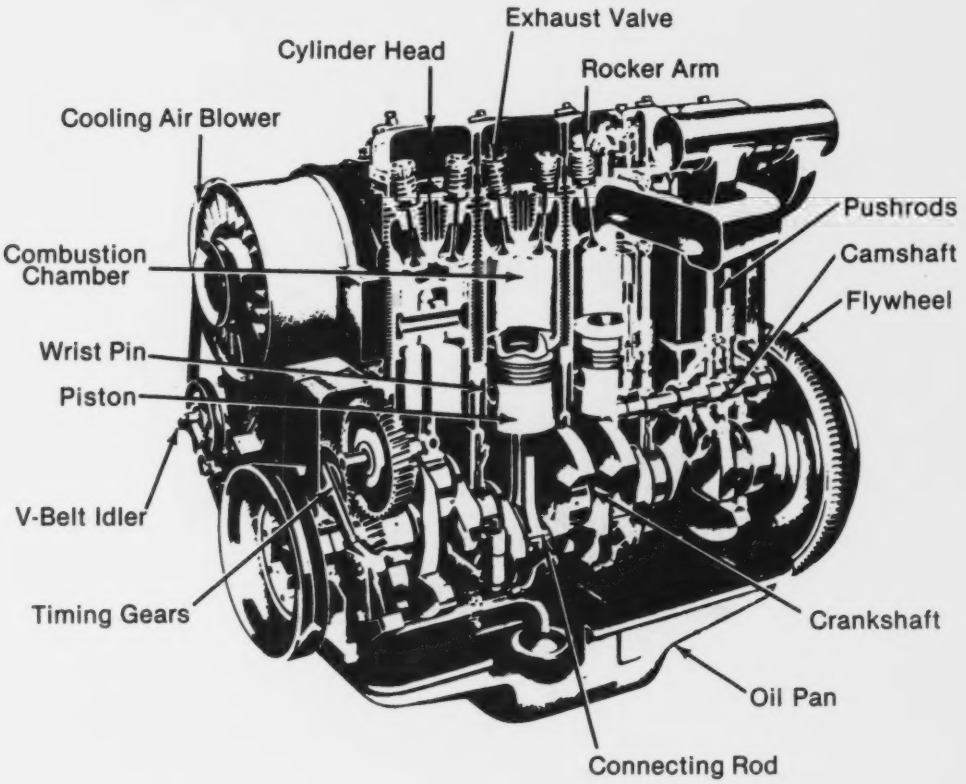


Used with permission of International Harvester Company.

INFORMATION SHEET

XXII. Basic parts of a diesel engine (Figure 18)

FIGURE 18



Source: Deutz Diesel Corporation.

XXIII. Purposes of a heavy flywheel

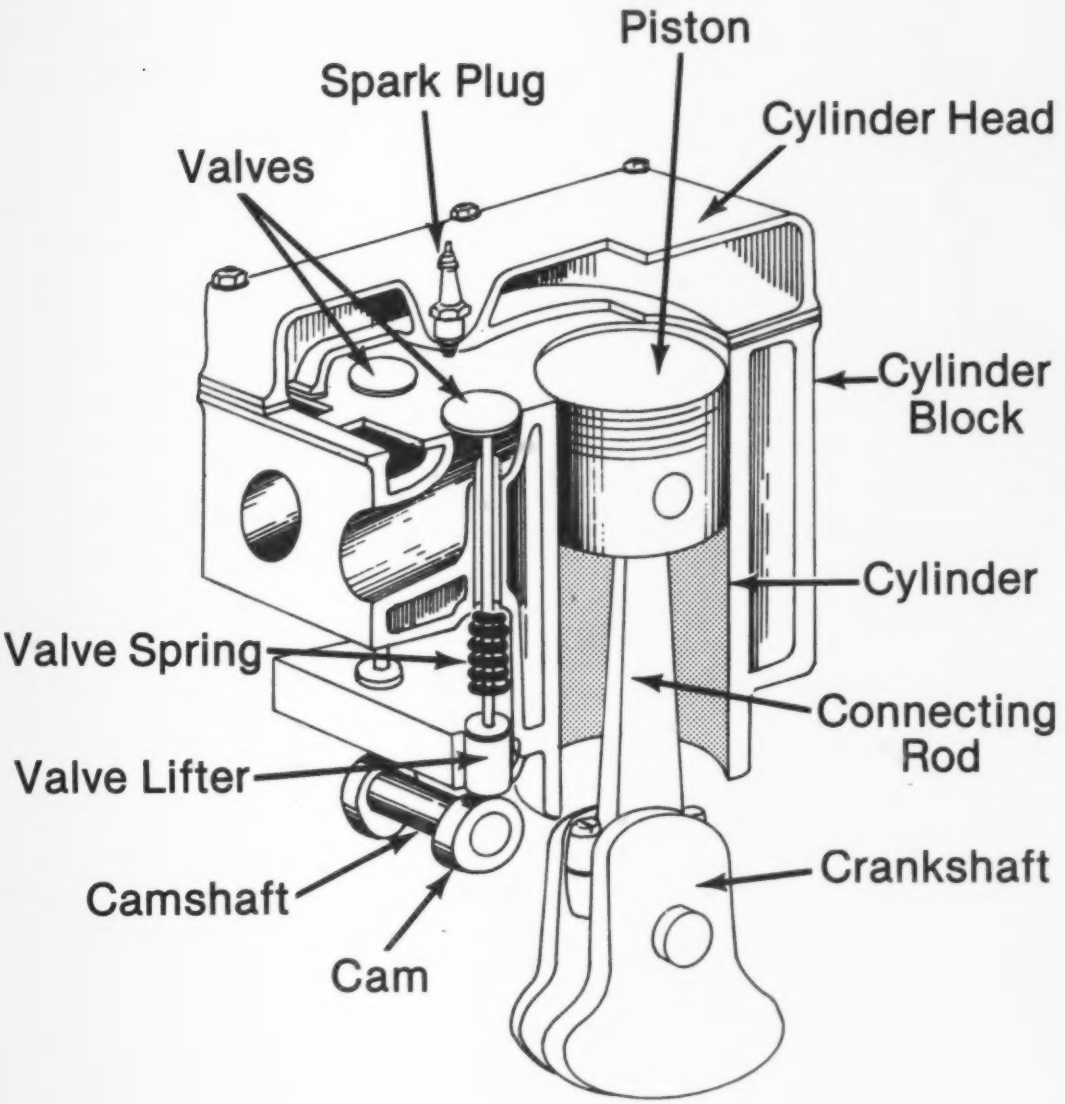
A. Smooths surges of the power strokes

B. Maintains crankshaft motion between power strokes

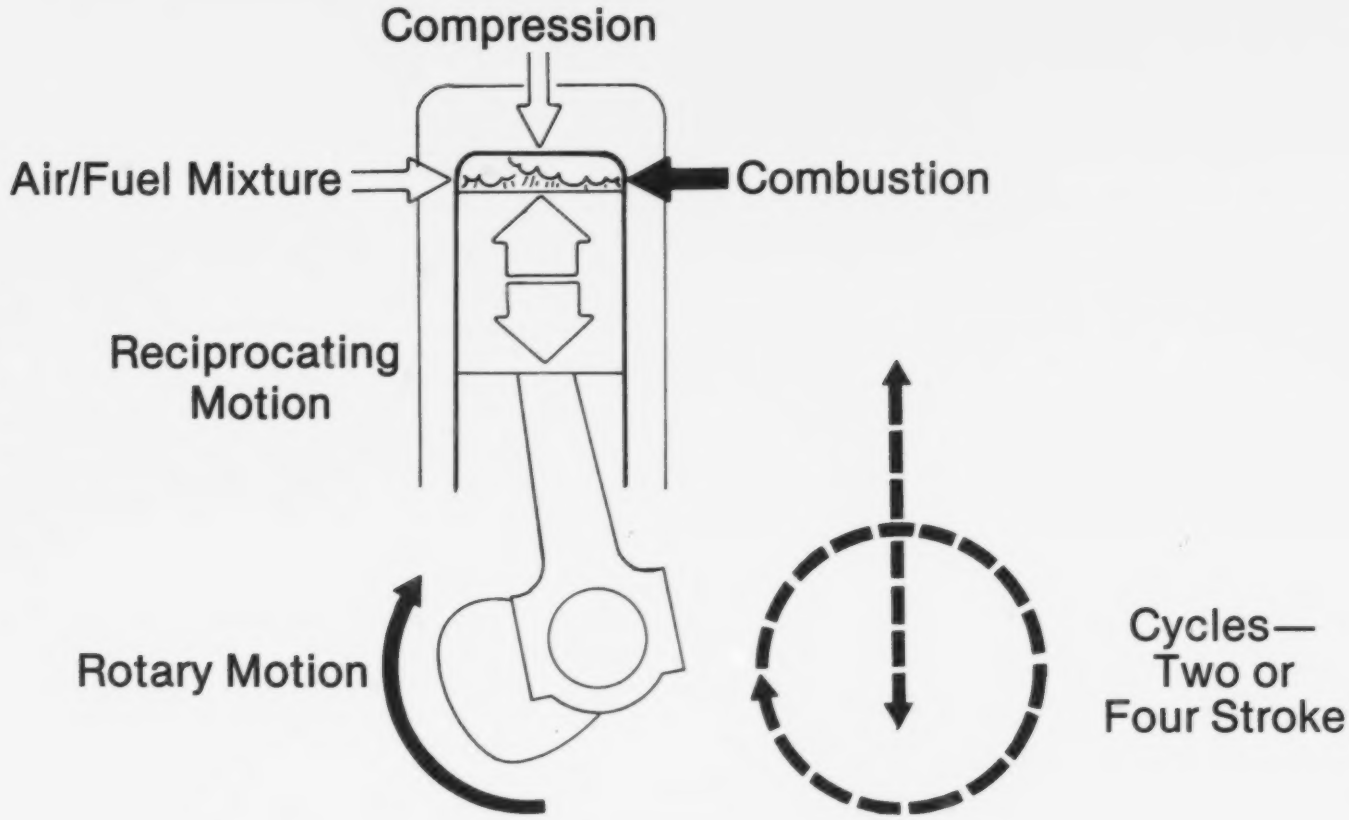
C. Develops kinetic energy when spinning

D. Provides gear teeth on outer rim for starting motor operation

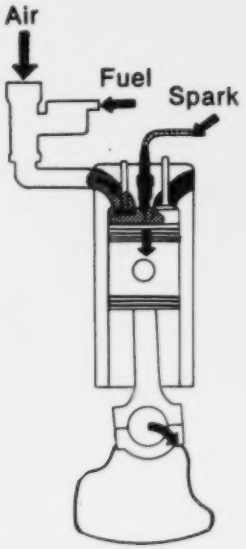
Parts of a Basic Internal-Combustion Engine



Process by Which a Gasoline Engine Converts Chemical Energy to Rotary Motion

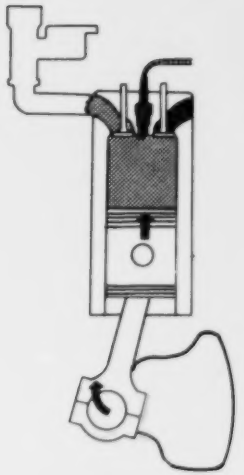


Four-Stroke-Cycle Gasoline Engine



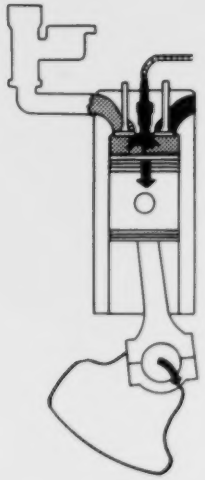
Intake Stroke

Air/fuel mixture is drawn into cylinder from carburetor through open intake valve by downstroke of piston.



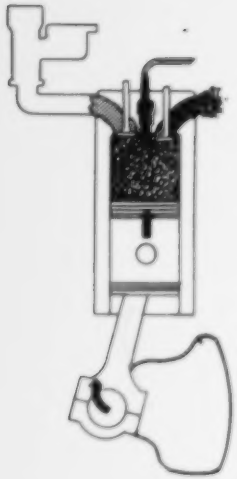
Compression Stroke

Air/fuel mixture is compressed by upstroke of piston. Both intake and exhaust valves are closed.



Power Stroke

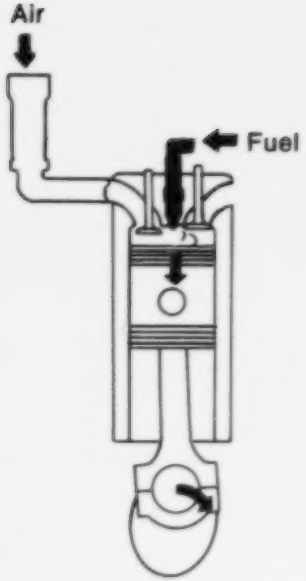
Compressed mixture is ignited by spark plug and expanding gases force piston to bottom of cylinder. Valves remain closed.



Exhaust Stroke

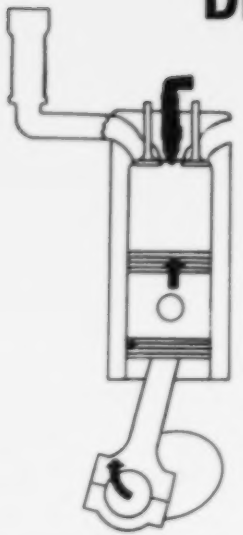
Piston on upstroke forces burned gases from cylinder through open exhaust valve.

Four-Stroke-Cycle Diesel Engine



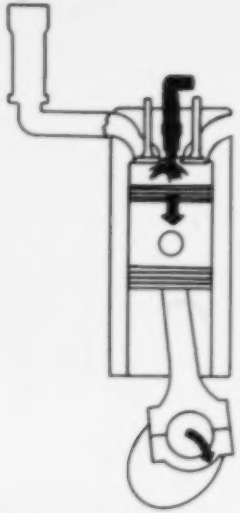
Intake Stroke

Air mixture is drawn or forced into combustion chamber. Intake valve is open.



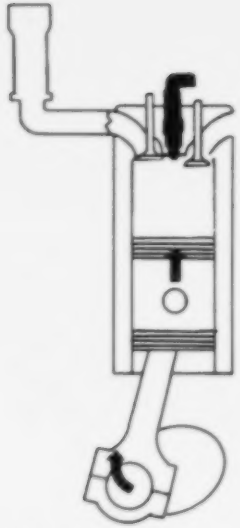
Compression Stroke

Air is compressed by upstroke of piston. Both intake and exhaust valves are closed.



Power Stroke

Temperature of air is raised due to high compression, which causes fuel to ignite as it is sprayed (injected) into combustion chamber. Expanding gases force piston to bottom of cylinder. Valves remain closed.



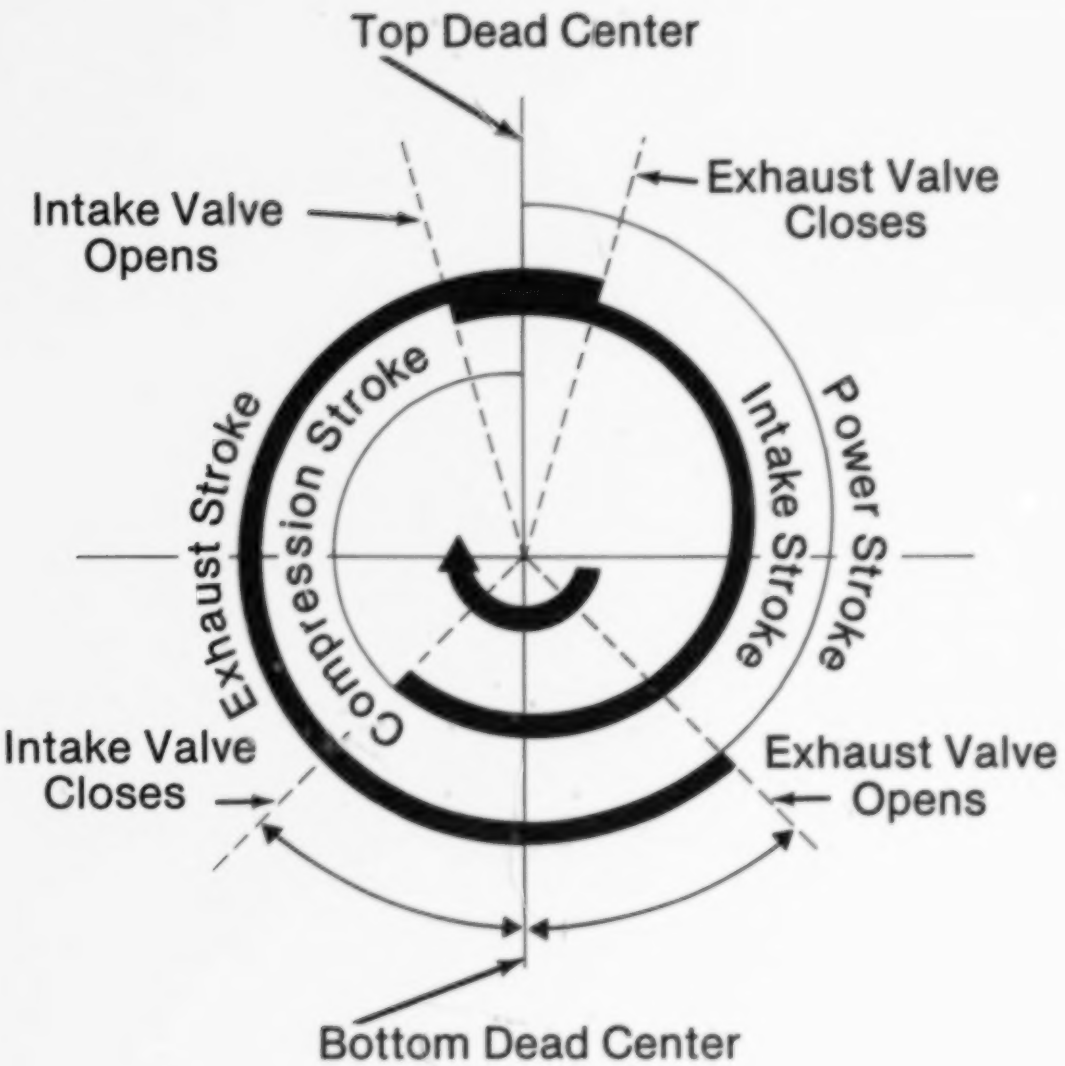
Exhaust Stroke

Piston on upstroke forces burned gases from cylinder through open exhaust valve.

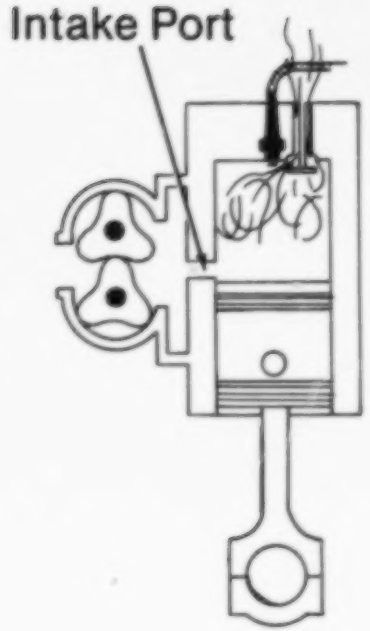
TM #4

HEM - 29-B

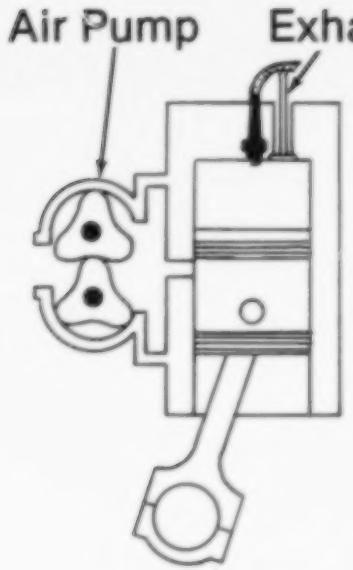
Valve Timing and Valve Overlap



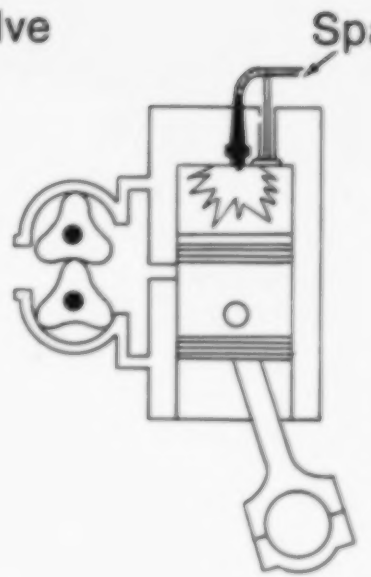
Two-Stroke-Cycle Gasoline Engine



Intake and Exhaust

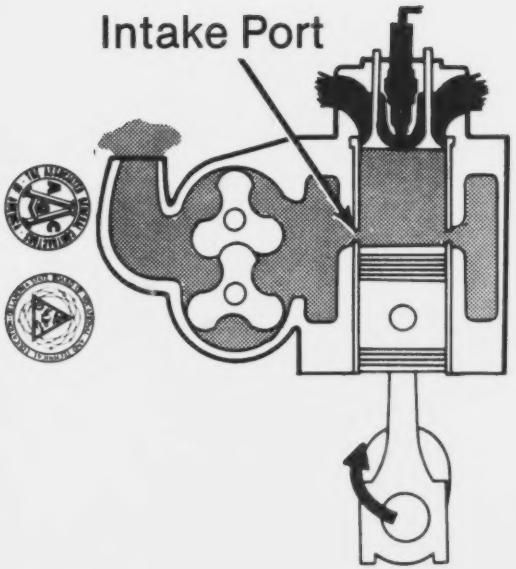


Compression Stroke

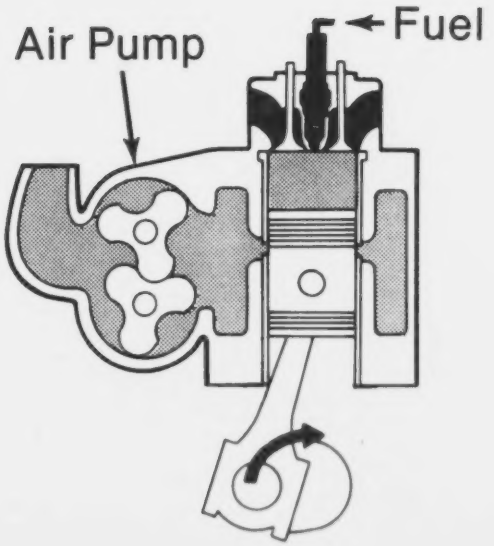


Power Stroke

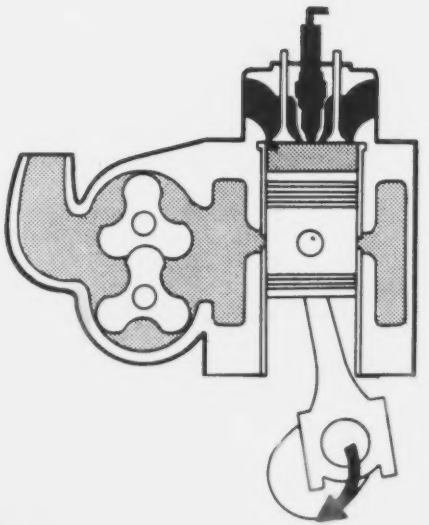
Two-Stroke-Cycle Diesel Engine



Intake and Exhaust



Compression Stroke



Power Stroke

342

343

TM #7

HEM - 35-B

BASIC ENGINE PRINCIPLES
UNIT I

ASSIGNMENT SHEET #1 — CALCULATE WORK

NAME _____ SCORE _____

This assignment sheet is a practice to help you become proficient in calculating and understanding how force is used to measure the amount of work accomplished in an engine.

Solve the following problems involving work. Use the formula

Work = Force x Distance.

Show your work.

A. How much work is accomplished if it takes 50 pounds of force to move a 250-pound water pump 35 feet?

Work = _____

B. How much work is accomplished if it takes 1,200 pounds of force for a backhoe to move 3,600 pounds of gravel 75 feet?

Work = _____

C. How much work is accomplished if it takes 475 pounds of force to raise a 725-pound truck 18 feet?

Work = _____

ASSIGNMENT SHEET #1

D. How much work is accomplished if it takes a bulldozer 650 pounds of force to pull a 300-pound log 185 feet?

Work = _____

E. How much work is accomplished if it takes 320 pounds of force to move a 400-pound air compressor 65 feet?

Work = _____

BASIC ENGINE PRINCIPLES
UNIT I

ASSIGNMENT SHEET #2 — CALCULATE HORSEPOWER

NAME _____ SCORE _____

This assignment sheet is a practice to help you understand how the horsepower in an engine accomplishes a certain amount of work in a given period of time.

Solve the following problems involving horsepower. Use the formula

$$\text{Horsepower} = \frac{\text{Force} \times \text{Distance}}{\text{Time (Sec)} \times 550}$$

or

$$= \frac{\text{Weight} \times \text{Distance}}{\text{Time (Sec)} \times 550}.$$

Show your work.

A. A 150-pound woman climbs 5 feet to the seat of a scraper in 10 seconds. How much horsepower does she expend?

Horsepower = _____

B. How much horsepower does a 2,200-pound loader develop climbing a 15-foot hill in 45 seconds?

Horsepower = _____

ASSIGNMENT SHEET #2

C. How much horsepower does an elevator with a 450-pound load develop moving up 65 feet in 90 seconds?

Horsepower = _____

D. If a crane raised a 700-pound load 85 feet in 35 seconds, how much horsepower would it expend?

Horsepower = _____

E. If a 10-ton roller moved up a 12-foot incline in 2 ½ minutes, how much horsepower would it expend?

Horsepower = _____

BASIC ENGINE PRINCIPLES
UNIT I

ASSIGNMENT SHEET #3 — CALCULATE TORQUE

NAME _____ SCORE _____

This assignment sheet is a practice to help you understand torque and how it is accomplished.

Solve the following problems involving torque. Use the formula

Torque = Force × Radius.

Write your answers in foot-pounds. Show your work.

A. If a force of 7 pounds is applied to a 12-inch ratchet wrench, what is the torque?

Torque = _____

B. If I applied 15 pounds of force to an 18-inch adjustable wrench, what would the torque be?

Torque = _____

C. If Judy applied 50 pounds of force with a 5-foot bar, what would the torque be?

Torque = _____

ASSIGNMENT SHEET #3

D. If an 18-inch torque wrench is used to apply 35 pounds of force, what is the torque?

Torque = _____

E. If a force of 120 pounds is used to loosen the lugs on a 38-inch wheel, using a foot-long wrench, what is the torque?

Torque = _____

BASIC ENGINE PRINCIPLES
UNIT I

ASSIGNMENT SHEET #4 — CALCULATE CUBIC-INCH DISPLACEMENT

NAME _____ SCORE _____

This assignment sheet is a practice to help you understand how larger engines (larger bore, longer stroke, and more cylinders) develop more cubic-inch displacement than smaller engines.

Solve the following problems involving cubic-inch displacement. Use the formula

$$\text{Cubic-Inch Displacement} = \frac{\pi \times \text{Bore}^2 \times \text{Stroke}}{4} \times \text{Number of Cylinders.}$$

Show your work.

A. A 2-cylinder engine with a 1 ½-inch bore and a 2-inch stroke has how much displacement?

Cubic-inch displacement = _____

B. How much displacement would there be in a 4-cylinder engine with a 2-inch bore and a 3-inch stroke?

Cubic-inch displacement = _____

ASSIGNMENT SHEET #4

C. If a 6-cylinder engine had a 3 1/2-inch bore and a 2 1/2-inch stroke, what would be the cubic-inch displacement?

Cubic-inch displacement = _____

D. A V-8 engine with a 4-inch bore and a 3 1/2-inch stroke has how much displacement?

Cubic-inch displacement = _____

E. An engine with 12 cylinders, 3 1/2-inch bore, and 3-inch stroke will have how much displacement?

Cubic-inch displacement = _____

BASIC ENGINE PRINCIPLES
UNIT I

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet #1

A. 1,750 foot-pounds

B. 90,000 foot-pounds

C. 8,550 foot-pounds

D. 120,250 foot-pounds

E. 20,800 foot-pounds

Assignment Sheet #2

A. 0.14

B. 1.33

C. 0.59

D. 3.09

E. 2.90

Assignment Sheet #3

A. 7 foot-pounds

B. 22.5 foot-pounds

C. 250 foot-pounds

D. 52.5 foot-pounds

E. 120 foot-pounds

Assignment Sheet #4

A. 7.07

B. 37.7

C. 144.32

D. 351.86

E. 346.36

BASIC ENGINE PRINCIPLES
UNIT I

TEST

NAME _____ SCORE _____

1. Match to their correct definitions terms associated with basic engine principles. Write the correct numbers in the blanks. Terms and definitions continue on the following page.

_____a.	Any agent that produces or tends to produce motion	1. Horsepower (hp)
_____b.	Result of force overcoming a resistance over a definite distance	2. psi
_____c.	Measurement of work accomplished in a given period of time	3. Control
_____d.	Stored energy	4. Work
_____e.	Bottom dead center	5. BDC
_____f.	Rate at which work is done	6. Power
_____g.	Ability to do work	7. Force
_____h.	Measurement of turning or twisting power	8. Mechanical power
_____i.	Resistance to relative motion between two bodies in contact	9. Potential energy
_____j.	Pounds per square inch; most common unit for measuring pressure	10. Torque (T)
_____k.	Transmission and control of motion through use of gears, pulleys, shafts, and other mechanical devices	11. Energy
_____l.	Cubic-inch displacement	12. Friction
_____m.	Series of events or operations that happens regularly and leads back to starting point	13. Cycle
_____n.	To exercise restraining or directing influences over working forces	14. CID

TEST

_____o. Diameter of cylinder

_____p. Top dead center

_____q. Energy in motion

_____r. Rapid combustion in an internal-combustion engine; results in knocking

_____s. Relay of working force

_____t. Total volume of air/fuel compressed by the piston in traveling from BDC to TDC

_____u. Back-and-forth motion

_____v. Mechanism that attaches to end of crankshaft and provides inertia to carry crankshaft around from one firing impulse to the other

_____w. Distance piston moves when traveling from TDC to BDC

15. Detonation
16. Kinetic energy
17. Bore
18. TDC
19. Reciprocating motion
20. Stroke
21. Displacement
22. Transmission
23. Flywheel

2. Discuss characteristics of energy.

_____

_____

_____

3. List three types of energy.

a. _____

b. _____

c. _____

4. Distinguish between potential and kinetic energy, the forms of available energy. Write a "P" in the blank before potential energy and a "K" in the blank before kinetic energy.

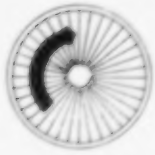
_____a. Stored energy, such as fuel and coal

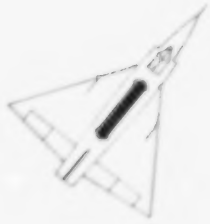
_____b. Energy in motion, such as wind, water, and burning gasoline

TEST

5. Identify types of motion. Write the correct names in the blanks.

Reciprocating **Rotary** **Linear**



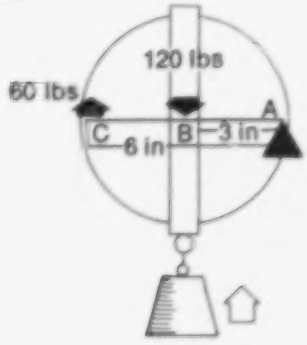


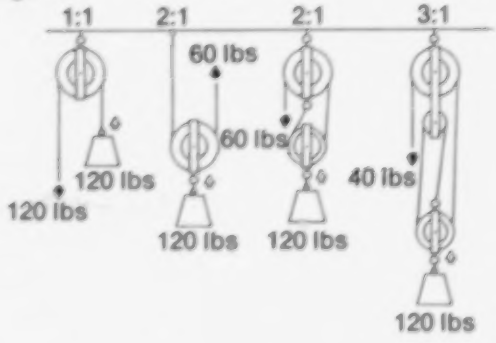
a. _____ b. _____ c. _____

6. Identify types of simple machines. Write the correct names in the blanks.

Lever
Wheel and axle
Pulley

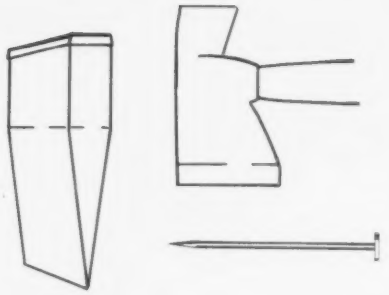
Inclined plane
Screw
Wedge



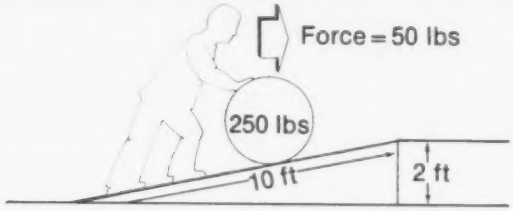


a._____

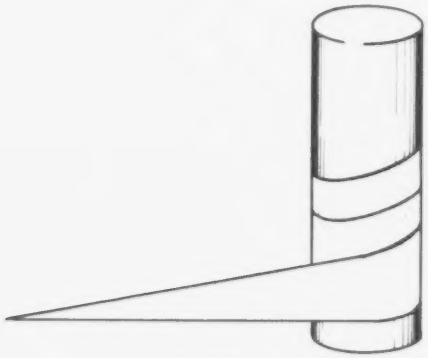
TEST



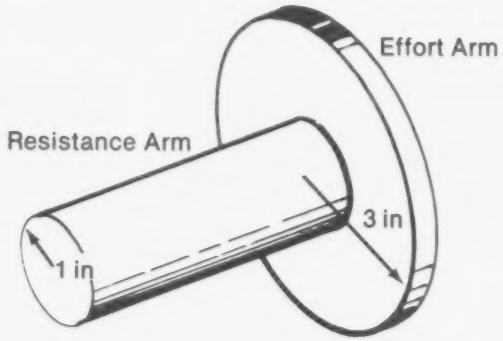
b. _____


Force = 50 lbs
250 lbs
10 ft
2 ft

c. _____

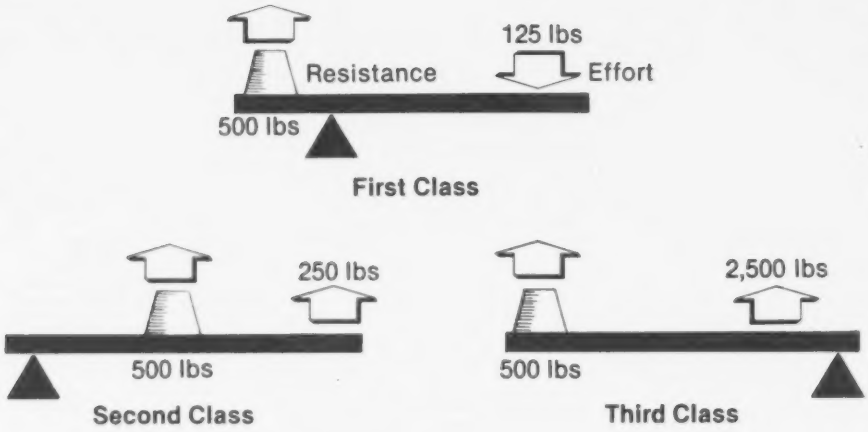


d. _____


Effort Arm
Resistance Arm
3 in
1 in

e. _____

TEST



f._____

7. List uses of simple machines.

   a. _____

   b. _____

   c. _____

8. Calculate the following problems, using the formula

   Work (W) = Force (F) x Distance (D).

   Show your work.

   a. How much work is accomplished if it takes 250 pounds of force to move a 300-pound pump 60 feet?

      Work = _____

TEST

b. How much work is accomplished if it takes a backhoe 175 pounds of force to raise a 375-pound boulder 12 feet?

Work = _____

9. Calculate the following problems, using the formula

$$\text{Horsepower (hp)} = \frac{\text{Force (F)} \times \text{Distance (D)}}{\text{Time (Sec)} \times 550}$$

or

$$= \frac{\text{Weight (W)} \times \text{Distance (D)}}{\text{Time (Sec)} \times 550}$$

Show your work.

a. How much horsepower would it take for a crane to hoist a 900-pound load 60 feet in 40 seconds?

Horsepower = _____

TEST

b. How much horsepower would a dozer develop to push a 1,200-pound boulder up a 20-foot incline in 3 minutes?

Horsepower = _____

10. Calculate the following problems, using the formula

Torque (T) = Force (F) × Radius (R).

Show your work.

a. If it took 45 pounds of force to turn a 3-foot round valve, what would be the torque?

Torque = _____

b. If a force of 12 pounds is applied to a 6-inch wrench, what would be the torque?

Torque = _____

TEST

11. State the function of heat engines.

_____

_____

12. Name types of heat engines. Write the correct names in the blanks.

a. _____ — Fuel produces heat energy inside the engine; engine converts heat energy to motion

b. _____ — Fuel produces heat energy outside the engine; heat is transmitted to engine by water or other means; engine converts heat energy to motion

13. Match the parts of a basic internal-combustion engine to their correct descriptions. Write the correct numbers in the blanks.

_____a. Hollow tube closed at one end

_____b. Cylindrical object that slides within the tube (cylinder), fitting tightly to seal other end of tube

_____c. Movable plug to open and close the cylinder in order to let in air/fuel mixture (intake valve) and to remove the burned fuel from cylinder (exhaust valve)

_____d. Main shaft of an engine, which, in conjunction with connecting rods, changes reciprocating motion of piston into rotary motion

_____e. Straight rod with one end connected to a pivot in the piston so that lower end can swing with the rotation of crankshaft

_____f. Shaft on which cams (lobes) and bearing journals are located; usually used to open the valves

1. Connecting rod
2. Valve
3. Cylinder
4. Camshaft
5. Crankshaft
6. Piston

TEST

14. Describe the process by which a gasoline engine converts chemical energy to rotary motion.

_____

_____

_____

_____

_____

_____

_____

15. Distinguish among operations of a four-stroke-cycle engine. Write an "I' in the blanks before operations of the intake stroke, a "C" before operations of the compression stroke, a "P" before operations of the power stroke, and an "E" in the blanks before operations of the exhaust stroke.

_____a. Air/fuel mixture is compressed tightly as piston moves up the cylinder

_____b. As piston moves down the cylinder, it draws air/fuel mixture into cylinder from carburetor

_____c. Piston travels up the cylinder, forcing burned gases out of cylinder and into exhaust manifold

_____d. When piston reaches bottom of cylinder (BDC), the intake valve closes, completing stroke

_____e. As piston reaches top of cylinder on compression stroke, a spark from the ignition system ignites the air/fuel mixture

_____f. Compression of fuel creates heat, which prepares the fuel for instant ignition

_____g. As piston reaches bottom of cylinder on power stroke, the exhaust valve opens

_____h. Piston is at topmost position (TDC), with intake valve open and exhaust valve closed

_____i. The burning gases expand very rapidly and force the piston down the cylinder

TEST

16. Discuss specific valve timing and valve overlap.

    a. Intake valve — _____

    _____

    _____

    b. Exhaust valve — _____

    _____

    _____

    c. Valve overlap — _____

    _____

    _____

17. Discuss operation of a two-stroke-cycle engine.

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

TEST

[redacted]

18. State the formula for calculating engine cubic-inch displacement.

Formula: _____

_____

19. State two results of increasing compression ratio.

a. _____

_____

b. _____

_____

20. Distinguish between characteristics of gasoline engines and characteristics of diesel engines. Write a "G" in the blanks before characteristics of gasoline engines and a "D" in the blanks before characteristics of diesel engines.

_____a. Takes fresh air directly into combustion chamber

_____b. Takes fresh air and fuel through carburetor and intake manifold, and then into combustion chamber

_____c. Has low compression ratio (7:1 to 12:1)

_____d. Has high compression ratio (16:1 to 22:1)

_____e. Injects fuel directly into combustion chamber

_____f. Is ignited by electrical spark

_____g. Is ignited by compression

_____h. Burns gasoline

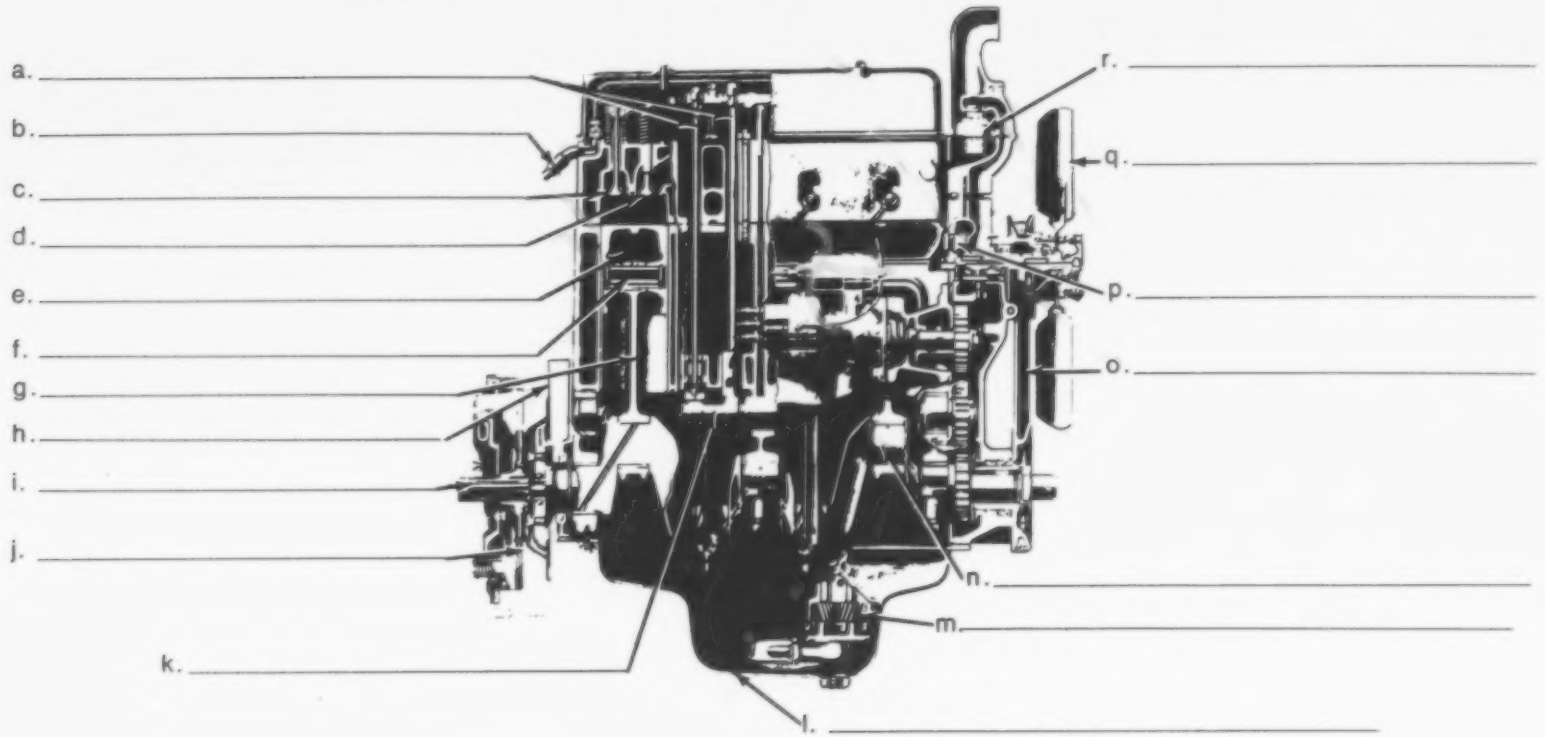
_____i. Burns low-grade fuel oil

_____j. Delivers fuel by air/fuel mixture drawn through carburetor and intake manifold into combustion chamber

TEST

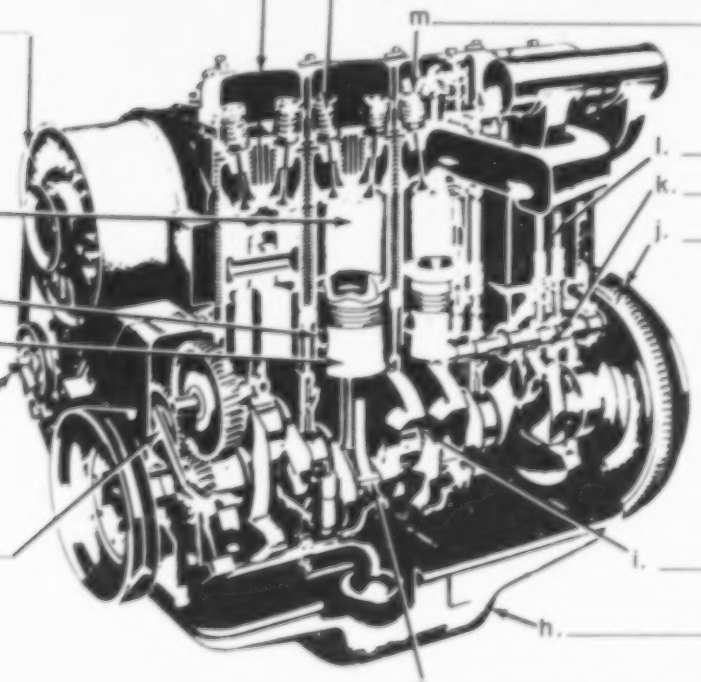
21. Identify basic parts of the gasoline engine illustrated below. Write the correct names in the blanks.

Pushrods	**Crankcase breather**	**Exhaust valve**
Piston	**Connecting rod**	**Intake valve**
Flywheel	**Clutch pilot shaft**	**Piston pin**
Clutch	**Camshaft and cams**	**Crankshaft**
Thermostat	**Gear oil pump**	**Cooling fan**
Water pump	**Fan belt**	**Oil pan**



22. Identify basic parts of the diesel engine illustrated below. Write the correct names in the blanks.

Cooling air blower	**Piston**	**Wrist pin**
Combustion chamber	**Crankshaft**	**Timing gears**
V-belt idler	**Flywheel**	**Exhaust valve**
Connecting rod	**Camshaft**	**Cylinder head**
Oil pan	**Pushrods**	**Rocker arm**



TEST

23. State two purposes of a heavy flywheel.

a. _____

b. _____

BASIC ENGINE PRINCIPLES
UNIT I

ANSWERS TO TEST

1.

a.	7	i.	12	q.	16
b.	4	j.	2	r.	15
c.	1	k.	8	s.	22
d.	9	l.	14	t.	21
e.	5	m.	13	u.	19
f.	6	n.	3	v.	23
g.	11	o.	17	w.	20
h.	10	p.	18		

2. Discussion should include the following
   a. Is ever present
   b. Cannot be created or destroyed
   c. Can only be changed from one kind of energy to another

3. Answer should include any three of the following

a.	Light	d.	Electrical
b.	Heat	e.	Nuclear
c.	Chemical	f.	Mechanical

4. a. P
   b. K

5. a. Rotary
   b. Linear
   c. Reciprocating

ANSWERS TO TEST

6. a. Pulley
   b. Wedge
   c. Inclined plane
   d. Screw
   e. Wheel and axle
   f. Lever

7. a. Increasing force
   b. Changing direction
   c. Changing speed

8. a. 15,000 foot-pounds
   b. 2,100 foot-pounds

9. a. 2.45
   b. 0.24

10. a. 135 foot-pounds
    b. 6 foot-pounds

11. To convert heat energy into usable power in the form of motion

12. a. Internal combustion
    b. External combustion

13. a. 3
    b. 6
    c. 2
    d. 5
    e. 1
    f. 4

14. Description should include the following
    a. Gasoline and air are introduced into upper end of cylinder
    b. Air/fuel mixture is ignited and burned, producing heat energy

ANSWERS TO TEST

c. Heat energy causes cylinder gases to expand

d. Expansion of the burning gases pushes piston down cylinder

e. Downward motion of piston transmits force to crankshaft through connecting rod, thus producing rotary motion

15.

a.	C	f.	C
b.	I	g.	E
c.	E	h.	I
d.	I	i.	P
e.	P		

16. Discussion should include the following

a. Intake valve — Opens approximately 15 degrees before intake stroke begins; remains open through intake stroke and 20 degrees into compression stroke

b. Exhaust valve — Opens approximately 40 degrees before exhaust stroke begins; remains open through exhaust stroke and 20 degrees into intake stroke

c. Valve overlap — Both intake and exhaust valves partially open; intake valve starts to open before exhaust valve is closed

17. Discussion should include the following

a. Air/fuel mixture is introduced into cylinder when piston is at the bottom

b. Pressure moves up the cylinder, compressing the mixture

c. Air/fuel mixture is ignited as piston reaches TDC

d. Expanding gases push piston down the cylinder, forcing crankshaft to rotate

e. As piston reaches bottom of cylinder again, burned gases are allowed to escape through one side of cylinder or exhaust valve as a fresh charge of air and fuel is introduced into the other side

ANSWERS TO TEST

18. Cubic-Inch Displacement (CID) $= \frac{\pi \times \text{Bore}^2 \times \text{Stroke}}{4} \times$ Number of Cylinders

19. Answer should include any two of the following

    a. Power increases as compression ratio increases

    b. Fuel economy increases as compression ratio increases

    c. As compression ratio is increased, higher-octane fuel is required to prevent engine knock due to detonation

    d. Higher compression ratios produce more exhaust-gas pollutants

20.

a.	D	f.	G
b.	G	g.	D
c.	G	h.	G
d.	D	i.	D
e.	D	j.	G

21.

a.	Pushrods	j.	Clutch
b.	Crankcase breather	k.	Camshaft and cams
c.	Exhaust valve	l.	Oil pan
d.	Intake valve	m.	Gear oil pump
e.	Piston	n.	Crankshaft
f.	Piston pin	o.	Fan belt
g.	Connecting rod	p.	Water pump
h.	Flywheel	q.	Cooling fan
i.	Clutch pilot shaft	r.	Thermostat

ANSWERS TO TEST

22.

a.	Cooling air blower	i.	Crankshaft
b.	Combustion chamber	j.	Flywheel
c.	Wrist pin	k.	Camshaft
d.	Piston	l.	Pushrods
e.	V-belt idler	m.	Rocker arm
f.	Timing gears	n.	Exhaust valve
g.	Connecting rod	o.	Cylinder head
h.	Oil pan		

23. Answer should include any two of the following

a. Smooths surges of the power strokes

b. Maintains crankshaft motion between power strokes

c. Develops kinetic energy when spinning

d. Provides gear teeth on outer rim for starting motor operation

ENGINE EVALUATION, REMOVAL, AND DISASSEMBLY
UNIT II

UNIT OBJECTIVE

After completing this unit, the student should be able to remove and disassemble an engine. The student will show this knowledge by completing the assignment sheet, job sheets, and unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match to their correct definitions terms associated with engine removal and disassembly.
2. List safety precautions to observe during engine removal and disassembly.
3. Select from a list conditions that cause low oil pressure.
4. List conditions that cause excessive oil consumption.
5. Select from a list items to inspect for engine condition evaluation.
6. Select from a list items to check prior to testing for internal engine noise.
7. Diagnose internal engine noise.
8. Identify special tools and equipment used in engine removal.
9. Arrange in order the steps in preparing engine for removal.
10. Select from a list techniques that ease engine disassembly and reassembly.
11. Select from a list items to inspect during engine disassembly.
12. Demonstrate the ability to
    a. Test engine compression on a gasoline engine.
    b. Perform a cylinder leakage test on a gasoline engine.
    c. Remove engine from a crawler tractor.
    d. Clean outside of engine.
    e. Remove exterior components of engine.
    f. Disassemble an engine.

ENGINE EVALUATION, REMOVAL, AND DISASSEMBLY
UNIT II

SUGGESTED ACTIVITIES

I. Suggested activities

A. Order materials planned to supplement unit.

(NOTE: Engine manufacturers are excellent sources for slide and film presentations on engines. Write to the appropriate company or manufacturer. Check with major engine manufacturers and equipment dealers for visual aids to demonstrate basic engine operations.)

B. Gather equipment and materials for job sheet demonstrations.

C. Provide students with objective sheet.

D. Discuss unit and specific objectives.

E. Provide students with information, assignment, and job sheets.

F. Discuss information and assignment sheets.

G. Demonstrate and discuss procedures outlined in job sheets.

H. Give test.

I. Complete appropriate section of competency profiles.

(NOTE: Competency profiles are available from AGC and CIMC.)

II. Instructional materials

A. Objective sheet

B. Suggested activities

C. Information sheet

D. Assignment Sheet #1 — Diagnose Internal Engine Noise

E. Answers to assignment sheet

F. Job sheets

1. Job Sheet #1 — Test Engine Compression on a Gasoline Engine

2. Job Sheet #2 — Perform a Cylinder Leakage Test on a Gasoline Engine

SUGGESTED ACTIVITIES

3. Job Sheet #3 — Remove Engine from a Crawler Tractor

4. Job Sheet #4 — Clean Outside of Engine

5. Job Sheet #5 — Remove Exterior Components of Engine

6. Job Sheet #6 — Disassemble an Engine

G. Test

H. Answers to test

III. Unit references

A. Armstrong, Ivan J. *Auto Mechanics*, Vols. II and III. Stillwater, Oklahoma: State Department of Vocational and Technical Education/Curriculum and Instructional Materials Center, 1978.

B. JI Case, *850 Crawler Service Manual 9-72942*, rev. 1. Racine, Wisconsin: JI Case, A Tenneco Company, 1975.

ENGINE EVALUATION, REMOVAL, AND DISASSEMBLY
UNIT II

INFORMATION SHEET

I. Terms and definitions

A. Blow-by — Leakage of unburned air-fuel mixture and some burned gases past piston rings into crankcase; occurs during compression and power stroke

B. Block-check — Special measuring device that, when inserted in the radiator filler neck of a running engine, can detect leakage of combustion gas into cooling system

C. Crankcase ventilation system — System that permits air to flow through engine crankcase to carry out blow-by gases and relieve any pressure buildup

(NOTE: There are two crankcase ventilation systems: the draft tube system and the positive crankcase ventilation system.)

D. Positive crankcase ventilation (PCV) — System used to recycle combustion (blow-by) gases from crankcase back to intake manifold to prevent hydrocarbons and carbon dioxide in blow-by gases from venting to outside air

E. Piston slap — Hollow, muffled, bell-like sound made by an excessively loose piston slapping cylinder wall

F. Preignition — Ignition of air-fuel mixture in engine cylinder before ignition spark occurs at spark plug; causes a knock in cylinder

G. Detonation — Engine knock caused by an uncontrolled second explosion of gases ahead of combustion flame front

H. Compression test — Measuring maximum pressure in cylinder with a pressure gauge while cranking engine with starter to test cylinder condition

I. Cylinder leakage test — Pressurizing cylinder on compression stroke with an external air source to gauge percentage of leakage and to determine what part of cylinder is causing the leak

J. Decarbonizing — Removing carbon from engine, either during overhaul or as a cylinder treatment

K. Engine loading — Operating engine under strain by using transmission or dynamometer

INFORMATION SHEET

L. Bell housing — Metal covering around flywheel and clutch, or torque converter assembly

M. Fire wall — Metal partition between driver's compartment and engine

N. Engine repair stand — Strong mobile stand for supporting an engine in various positions convenient for engine repair

O. Steam cleaner — Device used to heat water and mix steam with detergent; used to clean oil and dirt buildup

P. Engine subassemblies — Complete components of an engine

EXAMPLES: Cylinder head, manifolds, water pump

Q. Engine disassembly and inspection — Systematic method of removing parts and subassemblies in a particular sequence while checking for worn or damaged parts

II. Safety precautions to observe during engine removal and disassembly

A. Determine if hoist capacity is sufficient to handle engine weight

B. Stand clear of engine supported by a hoist

C. Do not work under vehicle while lifting engine

D. Check all equipment connections before lifting engine

E. Tighten all lift adapter bolts evenly while holding adapter plate firmly against engine

F. Do not raise engine higher than necessary

G. Lower engine to engine stand or near floor level as soon as possible after removal

H. Do not work on an engine supported only by a hoist

I. Keep floor of work area clean and dry at all times

J. Obtain help when handling heavy engine components

K. Center weight of engine on center of repair stand pivot, and securely attach engine to stand

L. Keep tools and work bench clean and orderly

INFORMATION SHEET

III. Conditions that cause low oil pressure

A. Worn connecting rod bearings

B. Worn main bearings

C. Worn camshaft bearings

D. Worn oil pump

E. Stuck oil pressure regulator valve

F. Broken pressure regulator valve spring in oil pump

G. Oil pump pickup screen raised above oil level in oil pan

H. Leakage in valve train

EXAMPLES: Broken push rod, rocker arm, or hydraulic lifter

I. Excessively thin or diluted oil

IV. Conditions that cause excessive oil consumption

A. Worn or stuck piston rings

B. Worn rod bearings

(NOTE: For every 0.001 inch of excessive rod-bearing clearance, the amount of oil slung from the bearing increases four times. This increases the amount of oil on the cylinder walls to such a degree that even good rings will be unable to wipe it off, thus allowing oil to reach the combustion chamber and be burned.)

C. Worn valve guides

D. Damaged or broken valve stem seals

E. Stuck PCV valve

F. Leaking intake manifold gasket

(NOTE: This condition will occur on engines that have the intake manifold covering the valve lifter chamber.)

G. External oil leaks

H. Vacuum diaphragm leaking on a double diaphragm fuel pump

INFORMATION SHEET

V. Items to inspect for engine condition evaluation

A. Oil for water and/or fuel contamination

B. Spark plugs for deposits on electrodes

(NOTE: Refer to a spark plug chart to determine causes of plug condition.)

C. Cooling system for compression leaks

(NOTE: Use block-check to check for compression leak into coolant.)

D. Oil leaks for location

E. Coolant leaks for location

F. Positive crankcase ventilation system for excessive blow-by

G. Air filter for evidence of dust abrasives entering engine through intake manifold

VI. Items to check prior to testing for internal engine noise

A. Fan or accessory drive belts for cracks or missing sections of belt core

B. Accessory components for noise

EXAMPLES: Alternator, air pump

C. Torsional vibration damper for looseness or improper installation

D. Flywheel or torque converter drive plate for loose bolts

E. Torque converter drive plate for cracks between hub area and converter attaching bolts

F. Heat riser valve for broken spring

G. Cylinders for carbon deposits

INFORMATION SHEET

VII. Internal engine noise diagnosis (Table 1; Assignment Sheet #1)

(NOTE: Test the following components with the engine at normal operating temperature.)

(CAUTION: At no time should an engine with a knock be tested at speeds above 2,500 rpm.)

TABLE 1

Component Making Noise	Type of Noise	Method of Distinguishing Noise
Fuel pump	Sharp, distinct, high-pitched knock localized in fuel pump area; knock may be intermittent	Listen to fuel pump and surrounding area with a stethoscope; noise should be loudest at fuel pump
Valve train	Variety of light-to-moderate knocks, chatters, pecks, or squeaks (NOTE: Valve noises are normally at half speed of engine speed while piston, rod, and crankshaft noises will be at engine speed.)	Remove valve cover and inspect valve train for broken or bent push rods, rocker arms, or valve springs; start engine and observe valve operation; check each valve for excessive lash
Rod bearing	Very sharp, solid knock in lower part of engine; much like hitting a solid steel bar with a hammer	Run engine at fast idle (1,500 to 2,000 rpm) with no load, and the bearing will knock; load engine and the knock should lessen or totally disappear; with engine at idle, remove and replace one spark plug wire at a time and listen to the knock; when the wire from the cylinder with the knocking bearing has been removed, you will hear a double knock; as the wire is replaced, the single knock will be heard again

INFORMATION SHEET

Component Making Noise	Type of Noise	Method of Distinguishing Noise
Main bearing	Deep, solid knock that at higher engine speeds will sound like a heavy rumbling noise (NOTE: A broken crankshaft will sound very similar to a main-bearing noise.)	Load engine at fast idle; knock will increase with load and decrease as load is relieved (NOTE: Rod or main bearing is accompanied by low oil pressure. In some cases, the engine will consume more oil because of the added oil slung from the bearing onto the cylinder walls.)
Piston	Very hollow, high-pitched, light-to-moderate knock	Start engine cold and run it at fast idle until it reaches operating temperature (piston noise will tend to lessen as engine warms up); with engine speed set to loudest knock, remove and replace one spark plug wire at a time until knock stops, indicating the cylinder with the knocking piston
Piston pin	Solid knock, but lighter than knock made by rod or main bearings and usually double in frequency (NOTE: Piston pin knocks at both top and bottom of each stroke.)	Raise and lower the engine speed slightly and listen for knock to become more severe as engine is accelerated; double knock will be about equal on deceleration
Timing chain	Clicking or pecking noise, much like a valve lifter, which remains consistently loud as engine speeds vary but changes frequency with engine speed	Operate engine at fast idle and listen to timing cover and general area around it with a stethoscope; noise should be louder on cover

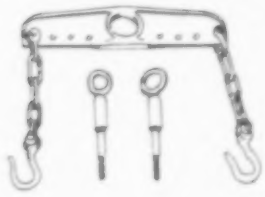
INFORMATION SHEET

VIII. Special tools and equipment used in engine removal (Figures 1-5)

A. Engine lift adapters (Figures 1 and 2)

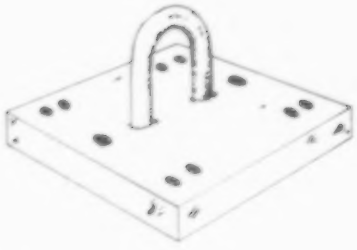
1. Cylinder head bolt

FIGURE 1



2. Carburetor

FIGURE 2



B. Chain hoist

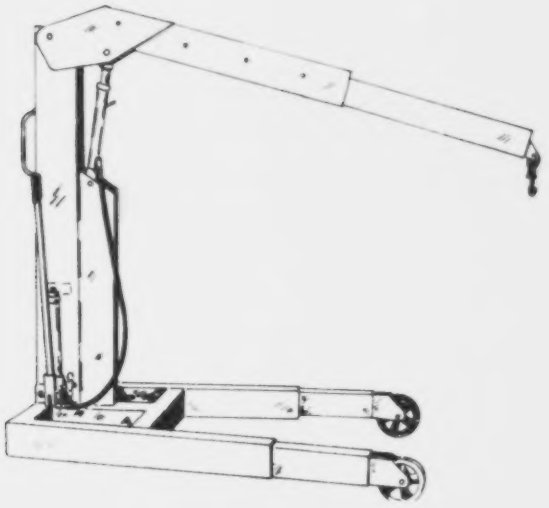
FIGURE 3

100 mm
A5
1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0
1.0 mm
1.5 mm
2.0 mm
ABCDEFGHIJKLMNOPQRSTUVWXYZ
abcdefghijklmnopqrstuvwxyz1234567890
ABCDEFGHIJKLMNOPQRSTUVWXYZ
abcdefghijklmnopqrstuvwxyz
1234567890

INFORMATION SHEET

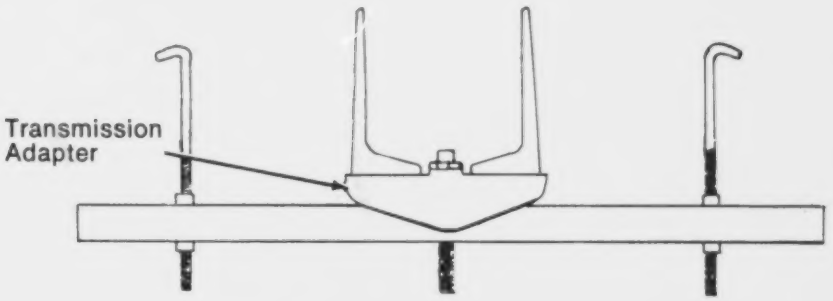
C. Hydraulic lift

FIGURE 4



D. Engine or transmission support

FIGURE 5



IX. Steps in preparing engine for removal

A. Prepare storage for radiator and other items before they are removed

B. Provide ample room for work around vehicle and hoist

INFORMATION SHEET

C. Begin at top and remove or disconnect all items possible

D. Place nuts, bolts, clips, and brackets taken from each side of engine in separate, marked parts trays

E. Raise vehicle (if necessary) and disconnect all items under vehicle

F. Place nuts, bolts, clips, and brackets taken from underside of vehicle in separate, marked parts tray

G. Lower vehicle to floor before removing engine

X. Techniques that ease engine disassembly and reassembly

A. Clean outside of engine as much as possible

B. Provide a clean, safe place for storage of parts and subassemblies

C. Provide storage trays for nuts, bolts, clips, springs, and other small parts

(NOTE: Reassembly will be faster and easier if a tray or compartment of a tray is available for each subassembly taken from the engine so that each group of fasteners can be separated.)

D. Keep all special braces, spacers, and special bolts with the subassembly to which they belong

EXAMPLES: Braces, nuts, bolts, belts for power steering

E. Sketch placement of accessories that may be difficult to reinstall

XI. Items to inspect during engine disassembly

A. Cylinder head gaskets for general condition

B. Cylinder head for visible cracks

C. Valve train for broken parts

D. Valves for burned condition

E. Cylinder block water jacket for sludge buildup

F. Cylinder block expansion plugs

G. Cylinder block for visible cracks

INFORMATION SHEET

H. Crankshaft journals for wear

I. Crankshaft bearings for general condition

J. Camshaft for general condition

K. All bolt hole threads for general condition

L. All observable parts for general condition

(NOTE: Instructor may add more items to this list as necessary.)

ENGINE EVALUATION, REMOVAL, AND DISASSEMBLY
UNIT II

ASSIGNMENT SHEET #1 — DIAGNOSE INTERNAL ENGINE NOISE

NAME _____ SCORE _____

In order to make necessary repairs, it is important that the mechanic know how to diagnose internal engine noises.

Complete the following chart for troubleshooting internal engine noise.

Component Making Noise	Type of Noise	Method of Distinguishing Noise
	Very sharp, solid knock in lower part of engine, much like hitting a solid steel bar with a hammer	
	Variety of light-to-moderate knocks, chatters, pecks, or squeaks	

ASSIGNMENT SHEET #1

Component Making Noise	Type of Noise	Method of Distinguishing Noise
	Sharp, distinct, high-pitched knock localized in fuel pump area; knock may be intermittent	
	Deep, solid knock that at higher engine speeds will sound like a heavy rumbling noise	
	Clicking or pecking noise, much like a valve lifter, which remains consistently loud as engine speeds vary but changes frequency with engine speed	

ASSIGNMENT SHEET #1

Component Making Noise	Type of Noise	Method of Distinguishing Noise
	Very hollow, high-pitched, light-to-moderate knock	
	Solid knock, but lighter than knock made by rod or main bearings and usually double in frequency	

ENGINE EVALUATION, REMOVAL, AND DISASSEMBLY
UNIT II

ANSWERS TO ASSIGNMENT SHEET

Assignment Sheet #1

Component Making Noise	Type of Noise	Method of Distinguishing Noise
Rod bearing	Very sharp, solid knock in lower part of engine; much like hitting a solid steel bar with a hammer	Run engine at fast idle (1,500 to 2,000 rpm) with no load, and the bearing will knock; load engine and the knock should lessen or totally disappear; with engine at idle, remove and replace one spark plug wire at a time and listen to the knock; when the wire from the cylinder with the knocking bearing has been removed, you will hear a double knock; as the wire is replaced, the single knock will be heard again
Valve train	Variety of light-to-moderate knocks, chatters, pecks, or squeaks	Remove valve cover and inspect valve train for broken or bent push rods, rocker arms, or valve springs; start engine and observe valve operation; check each valve for excessive lash
Fuel pump	Sharp, distinct, high-pitched knock localized in fuel pump area; knock may be intermittent	Listen to fuel pump and surrounding area with a stethoscope; noise should be loudest at fuel pump
Main bearing	Deep, solid knock that at higher engine speeds will sound like a heavy rumbling noise	Load engine at fast idle; knock will increase with load and decrease as load is relieved
Timing chain	Clicking or pecking noise, much like a valve lifter, which remains consistently loud as engine speeds vary but changes frequency with engine speed	Operate engine at fast idle and listen to timing cover and general area around it with a stethoscope; noise should be louder on cover

ANSWERS TO ASSIGNMENT SHEET

Component Making Noise	Type of Noise	Method of Distinguishing Noise
Piston	Very hollow, high-pitched, light-to-moderate knock	Start engine cold and run it at fast idle until it reaches operating temperature (piston noise will tend to lessen as engine warms up); with engine speed set to loudest knock, remove and replace one spark plug wire at a time until knock stops, indicating the cylinder with the knocking piston
Piston pin	Solid knock, but lighter than knock made by rod or main bearings and usually double in frequency	Raise and lower the engine speed slightly and listen for knock to become more severe as engine is accelerated; double knock will be about equal on deceleration

ENGINE EVALUATION, REMOVAL, AND DISASSEMBLY
UNIT II

JOB SHEET #1 — TEST ENGINE COMPRESSION ON A GASOLINE ENGINE

I. Equipment and materials

A. Basic hand tool set

B. Compression gauge

C. Squirt can containing 30-W oil

D. Safety glasses

E. Remote-control starter switch

F. Stethoscope or other listening device

G. Compression specifications for the particular engine being serviced

II. Procedure

A. Prepare engine for compression test

1. Operate engine until it reaches normal operating temperature

2. Remove air cleaner

3. Remove ignition coil secondary lead from center tower of distributor cap, and connect to a good ground

(NOTE: On the high energy electronic ignition [HEI], disconnect the distributor primary load wire while the ignition switch is in the OFF position.)

4. Block carburetor throttle valve and choke valve in wide-open position

(CAUTION: Make sure that automatic transmission models are in PARK, and standard transmissions are in NEUTRAL, with the park brake set.)

5. Remove all spark plugs

(NOTE: Clean around spark plugs before removing them so that dirt does not fall into engine as they are removed. This can be done by loosening spark plugs two or three turns and cranking the engine a few revolutions.)

6. Test battery condition; charge as necessary to provide consistently strong engine cranking during the test

JOB SHEET #1

B. Make a record sheet similar to that below to use during compression testing (Table 2)

TABLE 2

Record Sheet for Compression Testing

Cylinder Number	Dry Test Gauge Reading	Wet Test Gauge Reading	Test Results

C. Perform dry compression test

1. Connect remote-control starter switch to starter solenoid or relay
2. Install compression gauge hose in No. 1 cylinder
3. Connect gauge to hose
4. Crank engine to obtain five compression strokes of engine as indicated by fluctuation of gauge hand
5. Record the gauge reading next to No. 1 cylinder on record sheet
6. Repeat steps 3 through 5 on each of the remaining cylinders

(NOTE: Obtain compression specifications for the particular engine being serviced. Compression readings should not vary among cylinders more than 15 pounds per square inch [psi], and should not drop more than 15 percent below specified pressure.)

JOB SHEET #1

D. Perform a wet compression test

(NOTE: The wet compression test is used as a diagnostic tool when evaluating cylinder condition. The oil used on the wet test will seal the piston rings. If the compression rises significantly [15 psi or more], the rings are leaking compression. If compression does not rise, the valves or head gasket is defective.)

1. Inject approximately 2 tablespoons of 30-W oil into each cylinder
2. Connect a remote starter switch to starter solenoid or relay
3. Install compression gauge hose in No. 1 cylinder
4. Connect hose to gauge
5. Crank engine to obtain five compression strokes of engine as indicated by fluctuation of gauge hand
6. Record gauge reading next to No. 1 cylinder on record sheet
7. Repeat steps 4 through 6 on each of the remaining cylinders.

E. Compare the dry compression test with the wet compression test

F. Clean work area; put away all tools and equipment

ENGINE EVALUATION, REMOVAL, AND DISASSEMBLY
UNIT II

JOB SHEET #2 — PERFORM A CYLINDER LEAKAGE TEST ON A GASOLINE ENGINE

I. Equipment and materials

A. Basic hand tool set

B. Cylinder leakage tester

C. Safety glasses

D. Shop towels

E. Stethoscope or other listening device

F. Appropriate service manual

II. Procedure

A. Prepare engine for cylinder leakage test

1. Operate engine until it reaches normal operating temperature

2. Remove air cleaner

3. Remove all spark plugs

(NOTE: Clean around spark plugs before removing them so that dirt does not fall into the engine as they are removed. This can be done by loosening the spark plug two or three turns and cranking the engine a few revolutions.)

4. Remove ignition coil secondary lead from center tower of distributor cap; connect to a good ground

5. Block carburetor throttle and choke valve in wide-open position

6. Remove radiator cap

(CAUTION: To prevent being burned by hot coolant, loosen the cap and release pressure slowly before removing cap.)

7. Remove oil cap

JOB SHEET #2

B. Perform cylinder leakage test

1. Insert adapter into No. 1 cylinder by screwing adapter into spark plug hole (See Figure 6)

2. Attach whistle to adapter in No. 1 cylinder (See Figure 6)

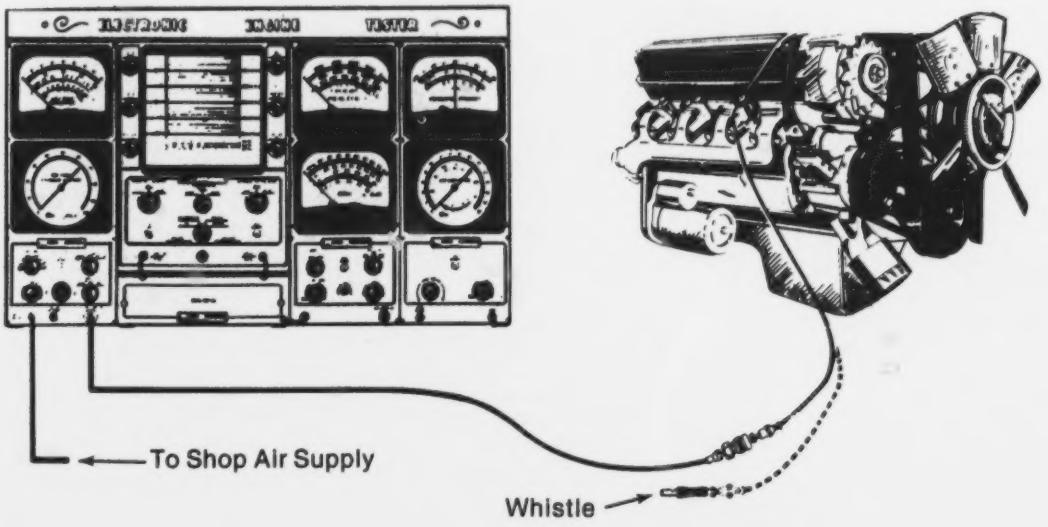
3. Rotate engine a fraction of a revolution at a time until whistle sounds

   (NOTE: The sounding whistle indicates that the piston is on compression stroke. To perform the leakage test, the piston must be very close to top dead center [TDC], or the test air pressure will push the piston back down the cylinder. An indicator plate can be used on the distributor to indicate when each piston in firing order is in the correct position for testing.)

4. Adjust cylinder leakage tester according to manufacturer's instructions

5. Connect tester hose to adapter (Figure 6)

FIGURE 6



6. Note the percentage of leakage on tester gauge

   (NOTE: This reading should be less than 20 percent. If reading is much higher, repeat steps 1 and 2 because both valves are probably not closed completely.)

JOB SHEET #2

7. Record this reading on a chart similar to that below (Table 3)

TABLE 3

		Check Location of Air Leakage			
Cylinder (By Firing Order)	Percent of Leakage	Carburetor	Exhaust Pipe	Oil Filler	Radiator

8. Listen for air escaping through carburetor, exhaust or tail pipe, and crankcase filler pipe

   (NOTE: It may be necessary to use a stethoscope or other listening device to determine exact location of air leakage.)

9. Check for air bubbles in radiator

10. Check appropriate column in chart

11. Test remaining cylinders in the same manner

    (NOTE: Use the condition chart with the diagnosis chart below [Table 4] to determine possible repairs needed. In cases where high percentages of leakage are noted on engines with comparatively low mileage [which could be attributed to stuck piston rings], it is advisable to treat the engine with a good grade of tune-up or break-in oil for a period of time and then retest before recommending that the engine be disassembled for major service.)

TABLE 4

Air Leakage Location	Probable Causes
Carburetor	Intake valve leaking
Exhaust pipe	Exhaust valve leaking
Adjacent cylinders, both showing a high percent of leakage	Leaking head gasket, crack in block or head
Radiator	Leaking head gasket, crack in cylinder block or head
Oil filler pipe	Worn rings or cylinder walls, stuck or broken rings, cracked pistons

C. Clean work area; clean and put away all tools and equipment

ENGINE EVALUATION, REMOVAL, AND DISASSEMBLY
UNIT II

JOB SHEET #3 — REMOVE ENGINE FROM A CRAWLER TRACTOR

I. Equipment and materials

A. Hoist or suitable engine lift

B. Engine pick-up adapter

C. Basic hand tool set

D. Drain pans for coolant, oil, and hydraulic oil

E. Penetrating oil

F. Engine stand

G. Parts trays

H. Safety glasses

I. Shop towels

J. Appropriate service manual

II. Procedure

(NOTE: This job sheet covers the removal of an engine with standard equipment. Be aware of accessories and special equipment on a particular vehicle, and plan the removal or disconnection of this equipment in your removal procedure.)

A. Position crawler on a level surface under hoist

(NOTE: On dozer models, rest the blade on the ground.)

B. Remove air cleaner cap and air cleaner extension

C. Remove side shield, engine panel, and brush guard from both sides of crawler

D. Unbolt voltage regulator from left side engine panel

E. Remove latch bolts from each corner of hood

F. Remove rear bolts from hood

JOB SHEET #3

G. Lift hood clear of muffler and air cleaner stacks

H. Disconnect foot throttle and remove floor board

I. Remove lift cylinder tubings

1. Move lift control lever back and forth to relieve hydraulic pressure
2. Remove pin from rod eye of both lift cylinders
3. Start engine and pull lift cylinder rods into cylinder tubes
4. Turn off engine
5. Move lift control lever back and forth to equalize pressures
6. Disconnect lift cylinder hoses on both sides

   (NOTE: Keep all openings plugged to prevent dirt from getting into the system.)
7. Secure lift cylinders out of way so that they do not hang free
8. Disconnect and remove crossover tubes and tubes on right side of engine

J. Remove muffler and air cleaner stack

K. Disconnect air restriction indicator cable from air intake line

L. Remove air cleaner

1. Disconnect hose at intake manifold
2. Detach air cleaner from mounting bracket
3. Remove air cleaner

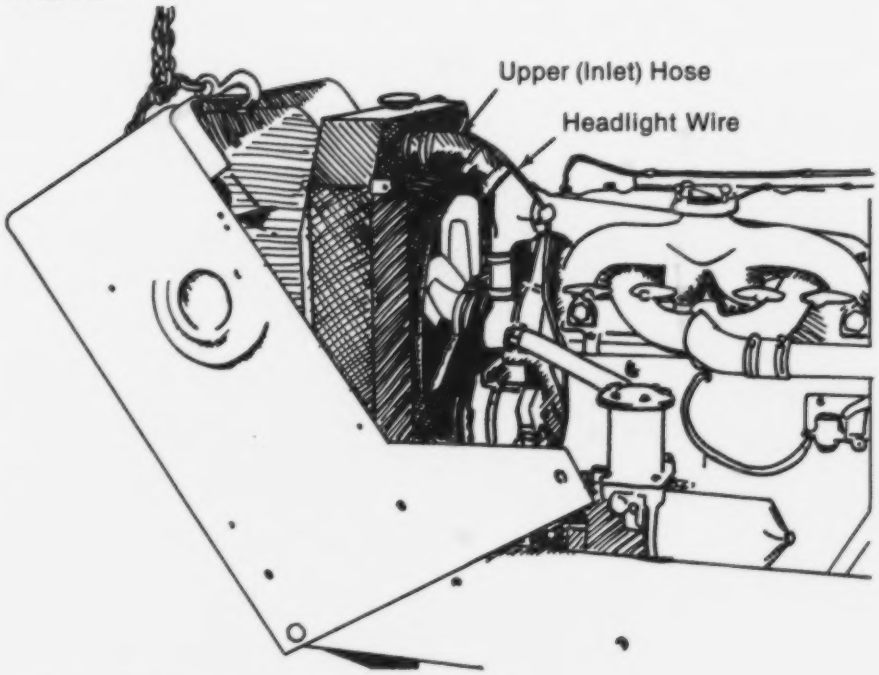
M. Remove radiator

1. Drain radiator
2. Disconnect radiator mounting strap from shroud

JOB SHEET #3

3. Attach hoist to shroud; then remove all bolts except the front corner bolts from shroud (Figure 7)

FIGURE 7



Used with permission of JI Case, a Tenneco Company.

4. Use hoist to tilt shroud forward until it rests against dozer blade
5. Remove hoist from shroud
6. Disconnect headlight wire from connector at radiator hose; unclamp from hose
7. Disconnect radiator hoses
8. Disconnect transmission oil cooler hoses from bottom of radiator
9. Remove radiator mounting bolts
10. Work radiator forward carefully until fan blades are clear of fan shroud; lift radiator out

    (CAUTION: Radiator is heavy. It may be necessary to have help to lift it out.)

N. Disconnect battery cables

O. Disconnect starter wires from solenoid on cranking motor

P. Disconnect connector between alternator and regulator

JOB SHEET #3

Q. Disconnect wires from alternator terminals

R. Remove regulator

S. Remove wiring harness from engine

T. Disconnect fuel line and fuel vent line at rear of engine

U. Disconnect throttle linkage from rear of fuel injection pump; remove the linkage

V. Disconnect and remove holding clamps as required for instrument panel lines

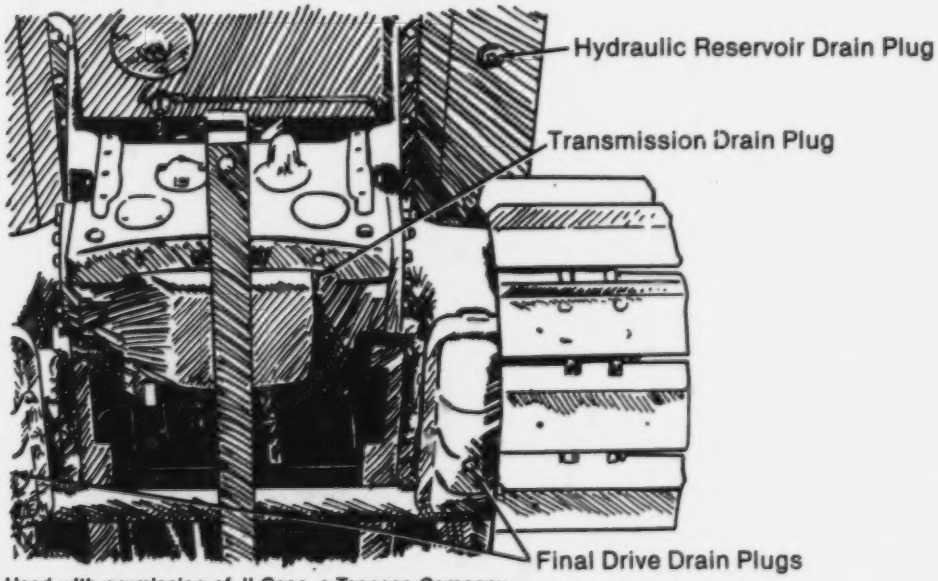
1. Remove clamp holding engine oil pressure gauge line from engine block
2. Remove clamp holding engine temperature sending line at water manifold
3. Remove clamp holding tachometer cable from engine block
4. Remove clamp holding temperature and pressure gauge lines from torque convertor

W. Drain hydraulic fluid from reservoir (See Figure 8)

X. Drain transmission (Figure 8)

(NOTE: If these oils are clean, keep them for reuse.)

FIGURE 8



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JOB SHEET #3

Y. Remove undercarriage guard from beneath torque converter

Z. Remove drive shaft

AA. Remove all tubes and hoses from converter, converter charging pump, and equipment pump

BB. Remove battery ground cable and any wiring clamps bolted to torque converter

CC. Attach hoist to engine and take up slack so that engine will be supported by hoist

DD. Remove front engine mounting bolts

EE. Remove engine frame mounting bolts

(CAUTION: Recheck to see that everything is disconnected.)

FF. Work engine forward and upward very carefully until it is free of crawler

GG. Mount and connect engine to engine stand

HH. Disconnect hoist

II. Clean work area; clean and put away all tools and equipment

ENGINE EVALUATION, REMOVAL, AND DISASSEMBLY
UNIT II

JOB SHEET #4 — CLEAN OUTSIDE OF ENGINE

I. Equipment and materials

A. Steam cleaner or car wash machine

B. Wire brush

C. Carbon scraper

D. Duct tape or suitable replacement

E. Engine degreaser or suitable replacement

F. Rubber apron, gloves, and overshoes

G. Safety glasses and full face shield

H. Shop towels

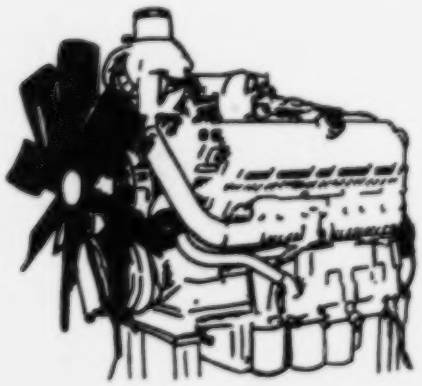
I. Basic hand tool set

II. Procedure

A. Seal all engine and accessory openings with duct tape or suitable replacement

(NOTE: Sealing prevents moisture and other contaminants from entering the system and causing damage such as rust corrosion or scoring from abrasive. See Figure 9.)

FIGURE 9



Used with permission of Deere and Company, Moline, Illinois.

JOB SHEET #4

B. Remove and label all drive belts

C. Remove any electrical wiring and accessories, such as alternator and starter, that remain on engine

D. Use carbon scraper to scrape heavily coated dirt from engine

(NOTE: Cleaning should be done in a specially designated area that will provide for easy cleanup after job is completed.)

E. Soak all engine areas with degreaser

(CAUTION: Do not let cleaning chemicals get inside alternator or starter; chemicals may remove insulation from the windings.)

F. Allow engine to soak for at least thirty minutes

G. Clean engine with a steam cleaner or other high-pressure, hot water source

(CAUTION: A rubber apron, gloves, and overshoes should be worn to protect clothing. A safety shield should be worn to protect the face.)

H. Scrape loose any stubborn dirt

I. Clean stubborn areas again with steam

J. Rinse engine with water

K. Move engine back to work area when it has dried sufficiently

L. Remove duct tape

M. Clean work area; put away all tools and equipment or prepare for disassembly (Job Sheets #5 and #6)

ENGINE EVALUATION, REMOVAL, AND DISASSEMBLY
UNIT II

JOB SHEET #5 — REMOVE EXTERIOR COMPONENTS OF ENGINE

I. Equipment and materials

A. Basic hand tool set

B. Puller (vibration damper)

C. Impact wrench

D. Impact socket set

E. Air supply

F. Parts trays

G. Safety glasses

H. Pulley puller

I. Shop towels

J. Appropriate service manual

II. Procedure

(NOTE: There is a definite sequence for removing components from an engine; therefore, the instructor must supervise and evaluate the procedure closely. The student should inspect each item as it is removed, observing its condition and looking for problems.)

A. Secure engine in an upright position on engine stand

B. Disconnect and remove torque converter

C. Remove power steering if engine is so equipped

D. Remove air pump if engine is so equipped

E. Remove hydraulic pump

F. Disconnect and remove alternator and brackets

G. Remove muffler, exhaust, and intake manifolds

H. Remove turbocharger if engine is so equipped

JOB SHEET #5

I. Remove fan and pulley

J. Remove water pump

K. Disconnect and remove oil filter, heat exchanger tube, and heat exchanger

L. Remove starting motor

M. Remove fuel transfer pump, lines, and filters

N. Remove fuel injection pump and lines

O. Remove glow plugs if engine is so equipped

P. Remove governor

Q. Remove torsional vibration damper and drive pulley assembly

(NOTE: Be sure to mark or tag all belts, hoses, and tubes when removing them.)

R. Remove air cleaner service indicator (restriction indicator)

S. Remove engine oiler if engine is so equipped

T. Remove crankcase breather, oil filter, and oil cooler

U. Remove all other lines and electrical connections that may hinder overhauling engine

V. Clean work area; put away all tools and equipment

ENGINE EVALUATION, REMOVAL, AND DISASSEMBLY
UNIT II

JOB SHEET #6 — DISASSEMBLE AN ENGINE

I. Equipment and materials

A. Basic hand tool set

B. Impact wrench

C. Inpact socket set

D. Safety glasses

E. Cylinder ridge reamer

F. Shop towels

G. Parts trays

H. Appropriate service manual

II. Procedure

(NOTE: While disassembling the engine, look at each item as it is removed, observing conditions and looking for problems. Some measurements and tests will be made during disassembly that will help in evaluating the total engine.)

A. Remove cylinder heads (See Figure 10)

(NOTE: On overhead camshaft models, refer to manufacturer's service manual for removal procedures.)

1. Remove valley chamber cover on V-block engines, and lifter side covers on in-line engines

2. Remove rocker arm cover(s)

3. Remove rocker arms as necessary for cylinder head removal

(NOTE: Mark rocker arms so that they can be replaced in their original positions.)

4. Remove push rods and store in sequence

(NOTE: If push rods are stored in sequence, they can easily be replaced in their original positions.)

5. Remove any braces or accessories on cylinder head not already removed

6. Remove cylinder head bolts

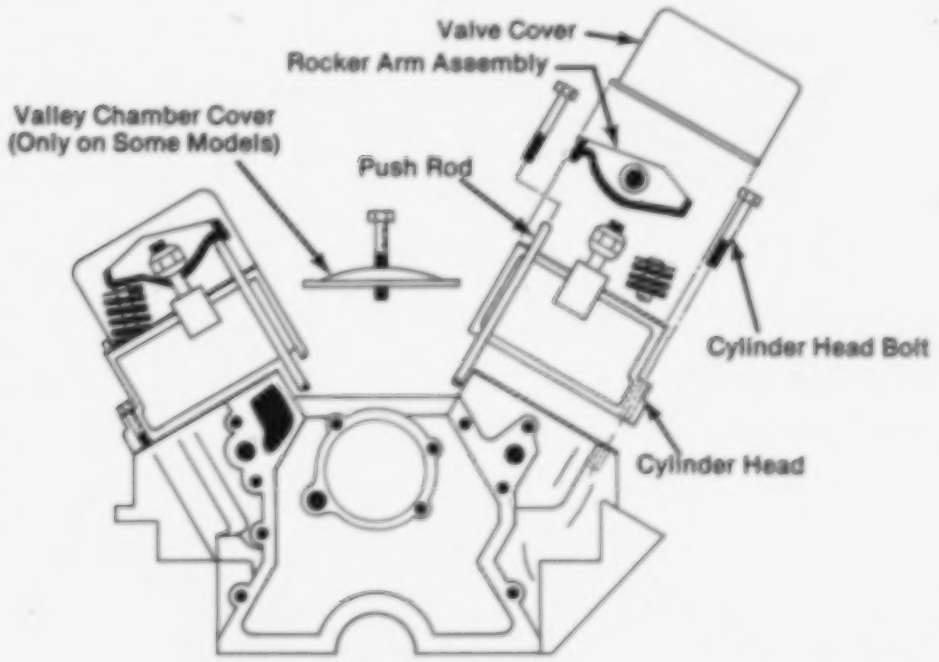
   (NOTE: Remove bolts on one cylinder head at a time on V-block engines.)

7. Remove cylinder head

   (NOTE: On V-block engines, mark or tag left and right side.)

   (CAUTION: To prevent damage to the cylinder head, use care when breaking the seal between the cylinder head and block.)

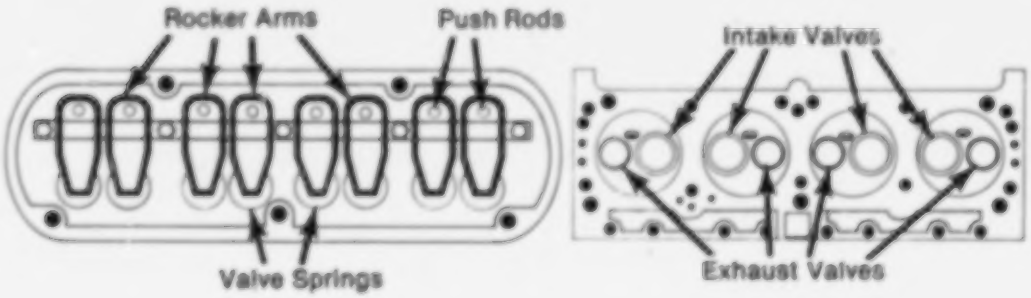
FIGURE 10



JOB SHEET #6

B. Inspect cylinder head for burned valves, broken rocker arms, push rods, head bolts, valve springs, or other visible problems (Figure 11)

FIGURE 11



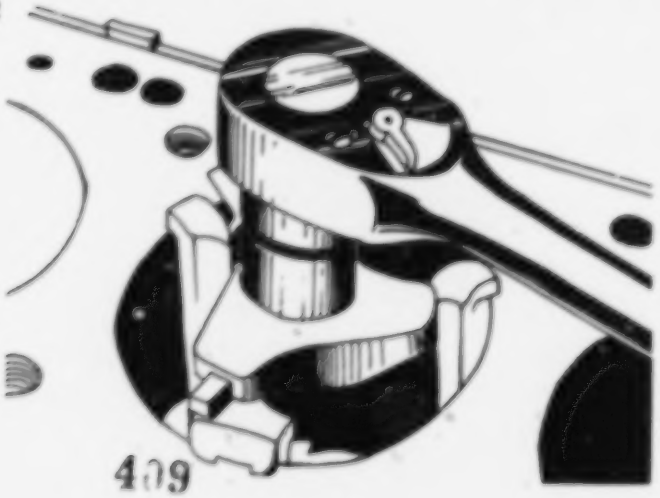
C. Remove cylinder ring ridge (Figure 12)

1. Clean cylinder block gasket surface around cylinders
2. Adjust the cutting tool so that it is slightly smaller than the cylinder diameter
3. Insert cutting tool in cylinder
4. Adjust cutter blade according to tool manufacturer's instructions

(NOTE: Check the cutting process frequently to prevent any damage to cylinder where rings travel.)

(CAUTION: Do not cut down into the ring travel zone when removing ridge. If cut too deep, cylinder may require reboring or replacement of the engine block or liner.)

FIGURE 12

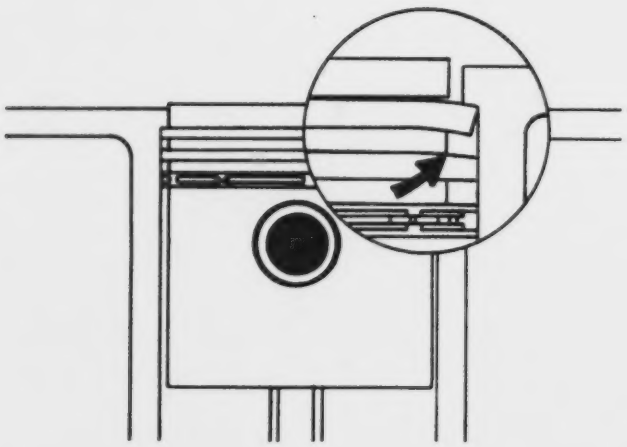


JOB SHEET #6

5. Cut the ring ridge off top of each cylinder

(CAUTION: Because the piston ring bands will be damaged, do not attempt to remove pistons from cylinders without cutting the ring ridge. See Figure 13.)

FIGURE 13



6. Clean cuttings out of cylinders

D. Remove valve lifters

(NOTE: Store lifters in the order in which they were removed so that they can be reinstalled in their original positions.)

E. Rotate engine on stand so that oil pan is up

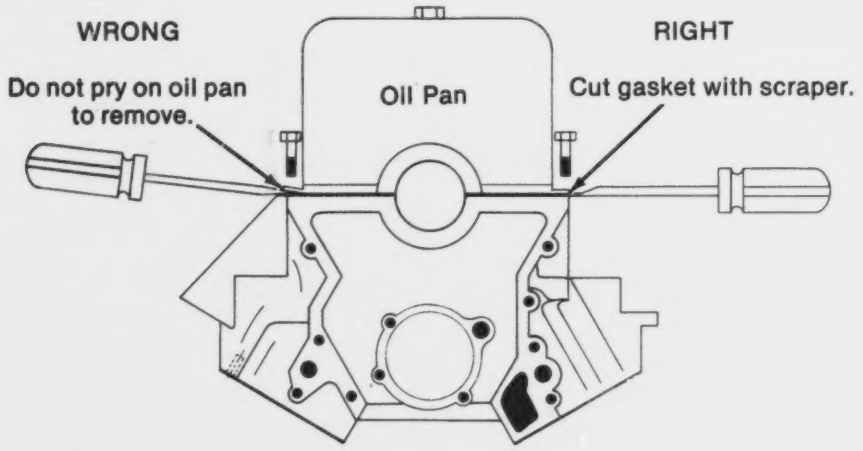
F. Remove oil pan attaching screws

JOB SHEET #6

G. Remove oil pan (Figure 14)

(NOTE: Use care not to warp oil pan gasket surface as it is unseated.)

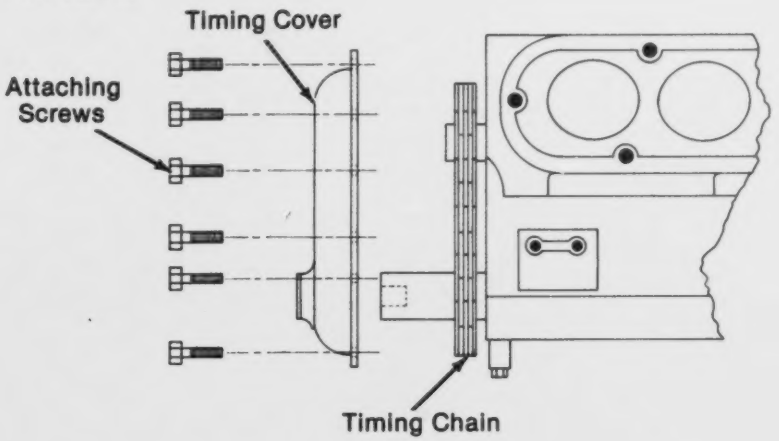
FIGURE 14



H. Remove timing cover attaching screws (Figure 15)

I. Remove timing cover (Figure 15)

FIGURE 15



JOB SHEET #6

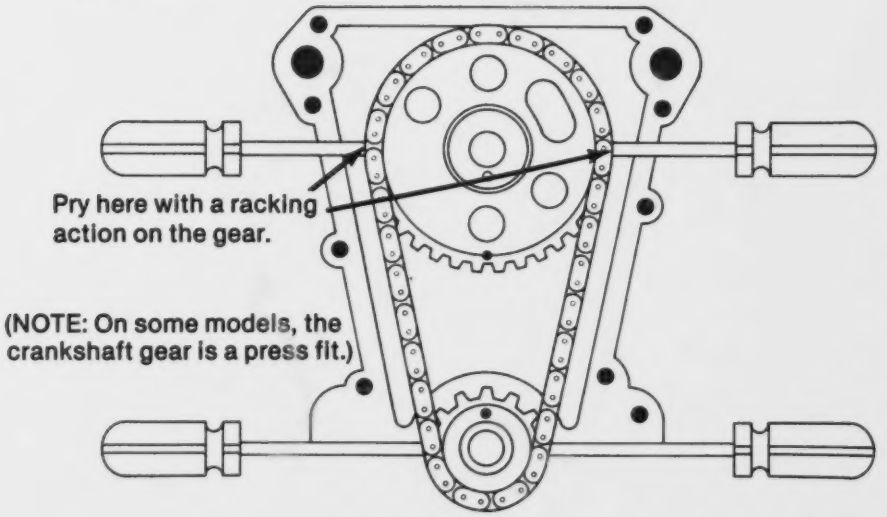
J. Remove fuel pump push rod on models so equipped

K. Remove timing gear retaining bolts or nuts

(NOTE: Some models will have press-on gears and will not have retaining bolts or nuts.)

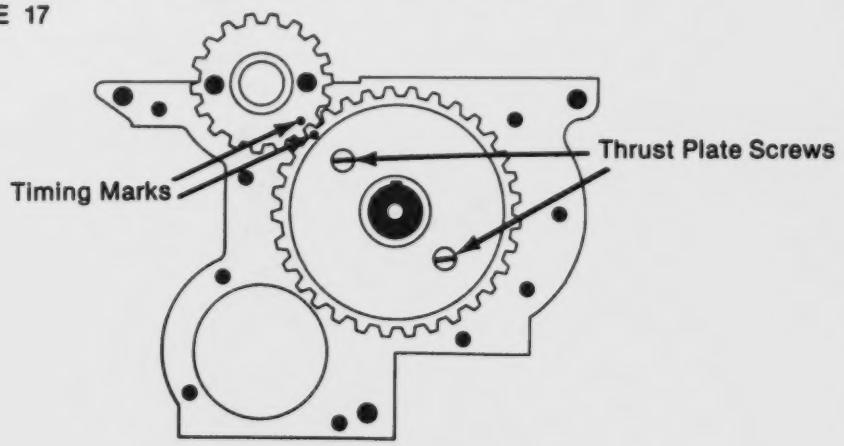
L. Remove cam gear and chain from camshaft by gently prying out on cam gear (Figure 16)

FIGURE 16



(NOTE: On models with press-on gears, remove gear and camshaft after removing thrust plate retaining bolts. See Figure 17.)

FIGURE 17



JOB SHEET #6

M. Remove camshaft thrust plate

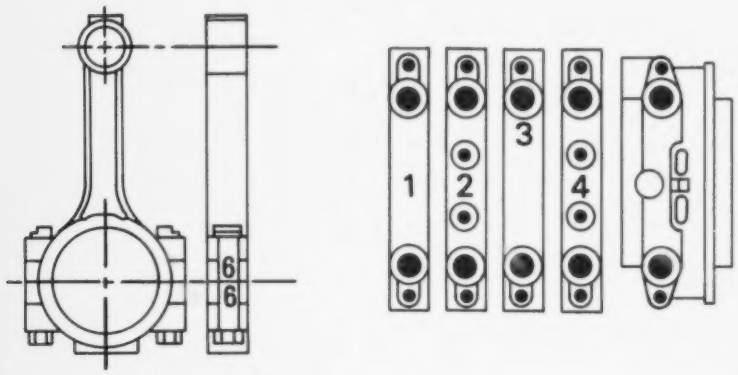
N. Remove oil pump and pickup screen assembly

O. Remove any oil baffles

P. Remove rear main bearing seal cap if separate from rear main bearing

Q. Check connecting rods and main caps for identification numbers; number if necessary (Figure 18)

FIGURE 18



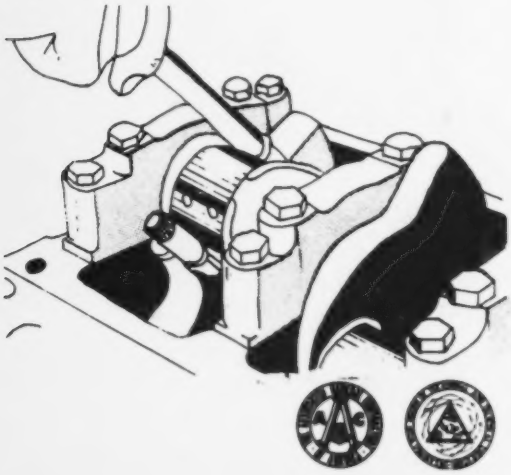
R. Rotate crankshaft until one crankpin is at its highest travel out of cylinder block

S. Remove rod cap from one of the connecting rods

T. Attach some type of protection device to both connecting rod bolts (Figure 19)

(NOTE: The crankshaft must be protected from the slightest contact with the rod bolts or other items that might mar the polished bearing surface. Short pieces of vacuum hose make good protection devices.)

FIGURE 19



JOB SHEET #6

U. Push piston and connecting rod assembly out of cylinder with a wooden hammer handle

(CAUTION: Never use metal objects to remove the piston and connecting rod assembly.)

V. Remove remaining piston assemblies in same manner

W. Replace rod caps on correct rods immediately after removal from engine

X. Remove all main bearing caps

(NOTE: Be sure that caps are numbered and marked to indicate direction that they were installed in the engine.)

Y. Lift crankshaft out of cylinder block with the aid of an assistant

(NOTE: Be sure to keep each main bearing cap bolt with its respective cap.)

Z. Visually inspect all components that have been removed for wear, damage, or any other problem that may require additional parts to be purchased

(NOTE: This inspection should be thorough in order to help evaluate the engine for repair or replacement.)

AA. Clean work area; clean and put away all tools and equipment

ENGINE EVALUATION, REMOVAL, AND DISASSEMBLY
UNIT II

TEST

NAME _____ SCORE _____

1. Match to their correct definitions terms associated with engine removal and disassembly. Write the correct numbers in the blanks. Terms and definitions are continued on the following page.

_____a.	Measuring maximum pressure in cylinder with pressure gauge while cranking engine with starter to test cylinder condition	1. Engine disassembly and inspection
_____b.	Special measuring device that, when inserted in the radiator filler neck of a running engine, can detect leakage of combustion gas into cooling system	2. Compression test
_____c.	Operating engine under strain by using transmission or dynamometer	3. Detonation
_____d.	System used to recycle combustion (blow-by) gases from crankcase back to intake manifold to prevent hydrocarbons and carbon dioxide in blow-by gases from venting to outside air	4. Block-check
_____e.	Systematic method of removing parts and subassemblies in a particular sequence while checking for worn or damaged parts	5. Preignition
_____f.	Ignition of air-fuel mixture in engine cylinder before ignition spark occurs at spark plug; causes a knock in cylinder	6. Blow-by
_____g.	Engine knock caused by an uncontrolled second explosion of gases ahead of combustion flame front	7. Positive crankcase ventilation (PCV)
_____h.	Leakage of unburned air-fuel mixture and some burned gases past piston rings into crankcase; occurs during compression and power stroke	8. Engine loading
_____i.	Pressurizing cylinder on compression stroke with an external air source to gauge percentage of leakage and to determine what part of cylinder is causing the leak	9. Cylinder leakage test

TEST

_____j. System that permits air to flow through engine crankcase to carry out blow-by gases and relieve any pressure buildup

_____k. Metal covering around flywheel and clutch, or torque converter assembly

_____l. Metal partition between driver's compartment and engine

_____m. Device used to heat water and mix steam with detergent; used to clean oil and dirt buildup

_____n. Complete components of an engine

_____o. Hollow, muffled, bell-like sound made by an excessively loose piston slapping cylinder wall

_____p. Strong mobile stand for supporting an engine in various positions convenient for engine repair

_____q. Removing carbon from engine, either during overhaul or as a cylinder treatment

10. Engine repair stand
11. Engine subassemblies
12. Bell housing
13. Piston slap
14. Crankcase ventilation system
15. Fire wall
16. Steam cleaner
17. Decarbonizing

2. List eight safety precautions to observe during engine removal and disassembly.

a. _____

_____

b. _____

_____

c. _____

_____

d. _____

_____

e. _____

_____

TEST

f. _____

_____

g. _____

_____

h. _____

_____

3. Select from the following list conditions that cause low oil pressure. Write an "X" in the blank before each correct answer.

_____a. Worn connecting rod bearings

_____b. Stuck thermostat

_____c. Excessively thin or diluted oil

_____d. Oil pump pickup screen raised above oil level in oil pan

_____e. Low detergent oil

_____f. Worn oil pump

_____g. Stuck oil pressure regulator valve

_____h. Broken pressure regulator valve spring in oil pump

_____i. Worn distributor shaft bearings

_____j. Worn camshaft bearings

_____k. Worn U-joints

_____l. Worn main bearings

_____m. Leakage in valve train

4. List five conditions that cause excessive oil consumption.

a. _____

b. _____

c. _____

d. _____

e. _____

TEST

5. Select from the following list items to inspect for engine condition evaluation. Write an "X" in the blank before each correct answer.

_____a. Carburetor choke for correct operation

_____b. Oil leaks for location

_____c. Air filter for evidence of dust abrasives entering engine through intake manifold

_____d. Oil for water and/or fuel contamination

_____e. Coolant leaks for location

_____f. Clutch for free play

_____g. Spark plugs for deposits on electrodes

_____h. Positive crankcase ventilation system for excessive blow-by

_____i. Fuel pump for correct pressure and capacity

_____j. Motor mounts for general condition

_____k. Cooling system for compression leaks

6. Select from the following list items to check prior to testing for internal engine noise. Write an "X" in the blank before each correct answer.

_____a. Heat riser valve for broken spring

_____b. Cylinders for carbon deposits

_____c. Exhaust pipe gaskets for wear

_____d. Accessory components for noise

_____e. Fan for proper blades

_____f. Torque converter drive plate for cracks between hub area and converter attaching bolts

_____g. Torsional vibration damper for looseness or improper installation

_____h. Fan or accessory drive belts for cracks or missing sections of belt core

_____i. Flywheel or torque converter drive plate for loose bolts

Component Making Noise	Type of Noise	Method of Distinguishing Noise
Rod bearing	Very sharp, solid knock in lower part of engine; much like hitting a solid steel bar with a hammer	e.
Valve train	Variety of light-to-moderate knocks, chatters, pecks, or squeaks	f.
Piston pin	Solid knock, but lighter than knock made by rod or main bearings and usually double in frequency	g.

TEST

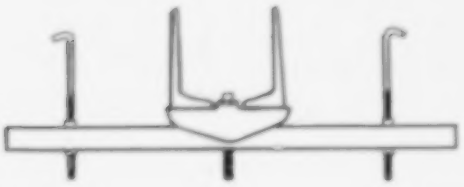
7. Diagnose internal engine noise by completing the following chart.

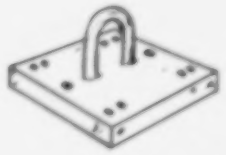
Component Making Noise	Type of Noise	Method of Distinguishing Noise
Piston	Very hollow, high-pitched, light-to-moderate knock	a. _____
Timing chain	Clicking or pecking noise, much like a valve lifter, which remains consistently loud as engine speeds vary but changes frequency with engine speed	b. _____
Main bearing	Deep, solid knock that at higher engine speeds will sound like a heavy rumbling noise	c. _____
Fuel pump	Sharp, distinct, high-pitched knock localized in the fuel pump area; knock may be intermittent	d. _____

TEST

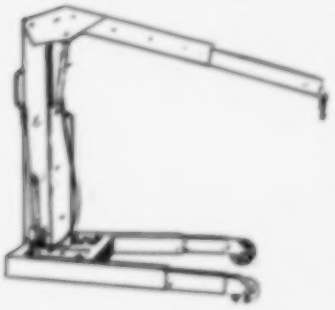
8. Identify special tools and equipment used in engine removal. Write the correct names in the blanks.

Engine or transmission support
Cylinder head bolt lift adapter
Chain hoist
Carburetor lift adapter
Hydraulic lift





a. _____ b. _____



c. _____ d. _____ e. _____

9. Arrange in order the steps in preparing engine for removal. Write a "1" before the first step, a "2" before the second step, and so on.

_____a. Begin at top and remove or disconnect all items possible

_____b. Place nuts, bolts, clips, and brackets taken from each side of engine in separate, marked parts trays

_____c. Raise vehicle (if necessary) and disconnect all items under vehicle

_____d. Provide ample room for work around vehicle and hoist

_____e. Lower vehicle to floor before removing engine

_____f. Place nuts, bolts, clips, and brackets taken from underside of vehicle in separate, marked parts tray

_____g. Prepare storage for radiator and other items before they are removed

TEST

10. Select from the following list techniques that ease engine disassembly and reassembly. Write an "X" in the blank before each correct answer.

_____a. Keep all special braces, spacers, and special bolts with the subassembly to which they belong

_____b. Sketch placement of accessories that may be difficult to reinstall

_____c. Keep tools stacked on the block for quick use

_____d. Provide a clean, safe place for storage of parts and subassemblies

_____e. Flush out inside of engine until it is clean

_____f. Provide storage trays for nuts, bolts, clips, springs, and other small parts

11. Select from the following list items to inspect during engine disassembly. Write an "X" in the blank before each correct answer.

_____a. Crankshaft bearings for general condition

_____b. Valve train for broken parts

_____c. Radiator for clogged cores

_____d. Cylinder block for visible cracks

_____e. All observable parts for general condition

_____f. Valves for burned condition

_____g. Exhaust pipe for rust holes

_____h. Cylinder head gaskets for general condition

_____i. All bolt hole threads for general condition

_____j. Crankshaft journals for wear

_____k. Cylinder head for visible cracks

_____l. Cylinder block expansion plugs

_____m. Motor mounts for poor banding

_____n. Cylinder block water jacket for sludge buildup

_____o. Camshaft for general condition

TEST

(NOTE: Test question 12 lists the job sheets. They are an important part of this test. If they have not been completed, check with your instructor.)

12. Demonstrate the ability to

    a. Test engine compression on a gasoline engine.

    b. Perform a cylinder leakage test on a gasoline engine.

    c. Remove engine from a crawler tractor.

    d. Clean outside of engine.

    e. Remove exterior components of engine.

    f. Disassemble an engine.

ENGINE EVALUATION, REMOVAL, AND DISASSEMBLY
UNIT II

ANSWERS TO TEST

1.

a.	2	g.	3	m.	16
b.	4	h.	6	n.	11
c.	8	i.	9	o.	13
d.	7	j.	14	p.	10
e.	1	k.	12	q.	17
f.	5	l.	15		

2. Answer should include any eight of the following

   a. Determine if hoist capacity is sufficient to handle engine weight

   b. Stand clear of engine supported by a hoist

   c. Do not work under vehicle while lifting engine

   d. Check all equipment connections before lifting engine

   e. Tighten all lift adapter bolts evenly while holding adapter plate firmly against engine

   f. Do not raise engine higher than necessary

   g. Lower engine to engine stand or near floor level as soon as possible after removal

   h. Do not work on an engine supported only by a hoist

   i. Keep floor of work area clean and dry at all times

   j. Obtain help when handling heavy engine components

   k. Center weight of engine on center of repair stand pivot, and securely attach engine to stand

   l. Keep tools and work bench clean and orderly

3. a, c, d, f, g, h, j, l, m

ANSWERS TO TEST

4. Answer should include any five of the following

   a. Worn or stuck piston rings

   b. Worn rod bearings

   c. Worn valve guides

   d. Damaged or broken valve stem seals

   e. Stuck PCV valve

   f. Leaking intake manifold gasket

   g. External oil leaks

   h. Vacuum diaphragm leaking on a double diaphragm fuel pump

5. b, c, d, e, g, h, k

6. a, b, d, f, g, h, i

7. a. Start engine cold and run it at fast idle until it reaches operating temperature (piston noise will tend to lessen as engine warms up); with engine speed set to loudest knock, remove and replace one spark plug wire at a time until knock stops, indicating the cylinder with the knocking piston

   b. Operate engine at fast idle and listen to timing cover and general area around it with a stethoscope; noise should be louder on cover

   c. Load engine at fast idle; knock will increase with load and decrease as load is relieved

   d. Listen to fuel pump and surrounding area with a stethoscope; noise should be loudest at fuel pump

   e. Run engine at fast idle (1,500 to 2,000 rpm) with no load, and the bearing will knock; load engine and the knock should lessen or totally disappear; with engine at idle, remove and replace one spark plug wire at a time and listen to the knock; when the wire from the cylinder with the knocking bearing has been removed, you will hear a double knock; as the wire is replaced, the single knock will be heard again

   f. Remove valve cover and inspect valve train for broken or bent push rods, rocker arms, or valve springs; start engine and observe valve operation; check each valve for excessive lash

   g. Raise and lower the engine speed slightly and listen for knock to become more severe as engine is accelerated; double knock will be about equal on deceleration

ANSWERS TO TEST

8. a. Engine or transmission support
   b. Carburetor lift adapter
   c. Hydraulic lift
   d. Chain hoist
   e. Cylinder head bolt lift adapter

9. a. 3
   b. 4
   c. 5
   d. 2
   e. 7
   f. 6
   g. 1

10. a, b, d, f

11. a, b, d, e, f, h, i, j, k, l, n, o

12. Performance skills evaluated to the satisfaction of the instructor

CLEANING, INSPECTING, AND RECONDITIONING GASOLINE ENGINES
UNIT III

UNIT OBJECTIVE

After completing this unit, the student should be able to clean, inspect, and recondition a gasoline engine. The student will show this knowledge by completing job sheets and unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match to their correct definitions terms associated with gasoline engines.
2. Match parts of the valve train to their correct functions.
3. List methods of driving the camshaft.
4. Identify the parts of the camshaft.
5. Label the parts of the cam lobe.
6. State types of valve lifters.
7. Identify the parts of a hydraulic valve lifter.
8. Discuss operation of a hydraulic valve lifter.
9. Label the parts of a valve.
10. Identify the parts of a valve assembly.
11. Identify types of valve springs and dampering devices.
12. Label types of valve stem seals.
13. Identify types of valve spring keepers.
14. Identify types of valve rotators.
15. State reasons valves must seat properly.
16. Select from a list major causes of valve burning.
17. Identify tools used to recondition valves.
18. State the purpose of the crankshaft.

OBJECTIVE SHEET

19. Label the parts of the crankshaft.
20. Label types of bearings used on the cam and crankshaft.
21. Distinguish between bearing spread and bearing crush.
22. Match bearing requirements to their correct definitions.
23. Discuss action of lubrication oil in an insert-type bearing.
24. Distinguish between purpose of torsional vibration damper and purpose of flywheel.
25. Label types of oil pumps.
26. Identify the parts of an oil pump.
27. Label cylinder wear patterns.
28. List methods of reconditioning cylinders.
29. State types of cylinder sleeves.
30. Label the parts of the cylinder block.
31. Name types of cylinder block core hole plugs.
32. Identify the parts of a piston and connecting rod assembly.
33. Identify types of compression rings.
34. Identify types of oil rings.
35. Match methods of piston heat and expansion control to their correct descriptions.
36. Match piston conditions to related causes.
37. State methods of lubricating cylinder walls and piston pins.
38. Identify tools and equipment used to recondition cylinders and pistons.
39. Identify types of piston pin locks.
40. Demonstrate the ability to
    a. Inspect timing gears and measure timing chain for stretch and camshaft end play.
    b. Inspect camshaft.

OBJECTIVE SHEET

c. Clean and inspect hydraulic lifters.

d. Disassemble, clean, and inspect cylinder head assembly.

e. Recondition cylinder head.

f. Check main bearing bore alignment.

g. Measure and inspect a crankshaft.

h. Fit a crankshaft bearing with Plastigauge.

i. Install a rear main bearing seal.

j. Disassemble, clean, and inspect an oil pump.

k. Remove piston ring ridge from cylinder.

l. Measure a cylinder for taper, wear, and out-of-round.

m. Hone a cylinder with a glaze-breaker hone.

n. Clean cylinder head surface and check for warpage.

o. Remove and replace a cylinder block core plug.

CLEANING, INSPECTING, AND RECONDITIONING GASOLINE ENGINES
UNIT III

SUGGESTED ACTIVITIES

I. Suggested activities

A. Order films and other materials to supplement unit.

(NOTE: Engine manufacturers and equipment dealers are the best sources for these materials.)

B. Gather equipment and materials for job sheet demonstrations.

C. Because unit is lengthy and complex, break it into smaller sections for ease of teaching and testing.

D. Make or obtain transparencies.

(NOTE: Transparencies are available from AGC and CIMC.)

E. Provide students with objective sheet.

F. Discuss unit and specific objectives.

G. Provide students with information and job sheets.

H. Discuss information sheet.

I. Demonstrate and discuss procedures outlined in job sheets.

J. Give test.

K. Complete appropriate section of competency profiles.

(NOTE: Competency profiles are available from AGC and CIMC.)

II. Instructional materials

A. Objective sheet

B. Suggested activities

C. Information sheet

D. Transparency masters

1. TM #1 — Parts of the Valve Train

2. TM #2 — Methods of Driving the Camshaft

SUGGESTED ACTIVITIES

3. TM #3 — Operation of a Hydraulic Valve Lifter
4. TM #4 — Lubricating Oil Action in an Insert Bearing
5. TM #5 — Cylinder Wear Patterns
6. TM #6 — Methods of Reconditioning Cylinders
7. TM #7 — Types of Cylinder Sleeves
8. TM #8 — Types of Cylinder Block Core Hole Plugs
9. TM #9 — Methods of Heat and Expansion Control
10. TM #10 — Piston Conditions and Related Causes
11. TM #11 — Piston Conditions and Related Causes (Continued)
12. TM #12 — Piston Conditions and Related Causes (Continued)
13. TM #13 — Cylinder Lubrication

E. Job sheets

1. Job Sheet #1 — Inspect Timing Gears and Measure Timing Chain for Stretch and Camshaft End Play
2. Job Sheet #2 — Inspect Camshaft
3. Job Sheet #3 — Clean and Inspect Hydraulic Lifters
4. Job Sheet #4 — Disassemble, Clean, and Inspect Cylinder Head Assembly
5. Job Sheet #5 — Recondition Cylinder Head
6. Job Sheet #6 — Check Main Bearing Bore Alignment
7. Job Sheet #7 — Measure and Inspect a Crankshaft
8. Job Sheet #8 — Fit a Crankshaft Bearing with Plastigauge
9. Job Sheet #9 — Install a Rear Main Bearing Seal
10. Job Sheet #10 — Disassemble, Clean, and Inspect an Oil Pump
11. Job Sheet #11 — Remove Piston Ring Ridge from Cylinder

SUGGESTED ACTIVITIES

12. Job Sheet #12 — Measure a Cylinder for Taper, Wear, and Out-of-Round

13. Job Sheet #13 — Hone a Cylinder with a Glaze-Breaker Hone

14. Job Sheet #14 — Clean Cylinder Head Surface and Check for Warpage

15. Job Sheet #15 — Remove and Replace a Cylinder Block Core Plug

F. Test

G. Answers to test

III. Unit reference — Armstrong, Ivan J. *Auto Mechanics*, Vol. II. Stillwater, Oklahoma: State Department of Vocational and Technical Education/Curriculum and Instructional Materials Center, 1978.

CLEANING, INSPECTING, AND RECONDITIONING GASOLINE ENGINES UNIT III

INFORMATION SHEET

I. Terms and definitions

A. Bearing — Surface that supports a moving load with minimum drag

B. Bearing crush — Slight distortion that holds bearing shell in place as engine operates

C. Bearing tang — Notch or lip on a bearing shell used to locate bearing correctly during assembly and operation

D. Bore — Diameter of a hole

EXAMPLE: Cylinder or crankshaft bore in block

E. Bushing — Spacing device; usually a sleeve with a bearing surface on the inside

F. Blow-by — Combustion gases that slip past piston and rings to get into crankcase

G. Cam duration — Number of degrees of crankshaft rotation while valve is open

H. Cam lift — Distance valve moves from closed to full-open

I. Camshaft — Shaft in engine that operates valves through a series of lobes

J. Crankpin — Portion of crankshaft to which connecting rod fastens

K. Cylinder block — Basic engine framework to which other engine parts are attached

L. Cylinder hone — Expandable rotating tool with abrasive fingers turned by an electric motor; used to clean and smooth inside surface of cylinder

M. Cylinder head — That part of engine that encloses cylinder bores and contains water jacket and sometimes valves

N. Idler gear — Rotating gear that does not transfer a load

O. I-head — Engine in which cylinder head and valves are over the cylinder

(NOTE: This is the most common valve arrangement.)

P. Journal — Surface on which a bearing operates

INFORMATION SHEET

Q. Knurl — To roughen a piece of metal by pressing a series of crosshatched lines into the surface, thereby raising the area between these lines

(NOTE: This process is used to enlarge worn piston skirts.)

R. Land — Surface between piston ring grooves

S. Lifter valley — Chamber between cylinder bores on a V-block engine

T. Oil control ring — Lower ring or rings on a piston; designed to prevent excessive amounts of oil from working up into combustion chamber

U. Overhead camshaft — Camshaft located in cylinder head or heads

V. Pilot bearing — Bearing in back of crankshaft that supports front of clutch shaft

W. Piston slap — Sound made by a piston with excess skirt clearance as crankshaft moves across top center

X. Plastigauge — Small-sized plastic thread for measuring clearances

(NOTE: Plastigauge is smashed between bearing and journals and then measured to determine clearance.)

Y. Ream — To size a hole to exact dimensions with a cutting tool called a reamer

Z. Pop-up — Raised portion of piston head

AA. Ring-expander tool — Special tool used to expand piston rings for installation on piston

BB. Ring ridge — That portion of cylinder above the top limit of ring travel

(NOTE: In a worn cylinder, this area is of smaller diameter than the remainder of the cylinder.)

CC. Torsional vibration damper — Round, weighted device attached to front of crankshaft to minimize torsional (twisting) vibration of shaft

DD. Valve lasher or clearance adjustment — Looseness designed into valve trains so that valve will seat properly

EE. Valve lifter — Cylindrical part of engine that rests on a cam of camshaft so that valve is opened as cam rotates

(NOTE: The valve lifter may also be called a *tappet* or *cam follower.*)

FF. Valve train — Valve-operating mechanism of engine

INFORMATION SHEET

II. Parts of the valve train and their functions (Transparency #1)

(NOTE: The following are parts of the valve train in an I-head system with camshaft in cylinder block.)

A. Valve — Opens and closes intake and exhaust ports connected to cylinder

B. Valve spring — Forces valve to close

C. Rocker arm — Changes direction of motion in valve train and pushes valve off its seat

D. Push rod — Transmits motion from lifter to rocker arm

E. Lifter — Rides along cam lobe; changes rotating motion to reciprocal motion

F. Camshaft — Operates valve lifters by rotating cam lobes against lifters

G. Cam gear — Turns camshaft and is used in timing camshaft to crankshaft

H. Crankshaft gear — Drives cam gear

(NOTE: The camshaft rotates at one-half the speed of the crankshaft, resulting in a 2:1 ratio in the gears.)

III. Methods of driving the camshaft (Transparency #2)

A. Gear

B. Chain

C. Belt

INFORMATION SHEET

IV. Parts of the camshaft (Figures 1 and 2)

FIGURE 1

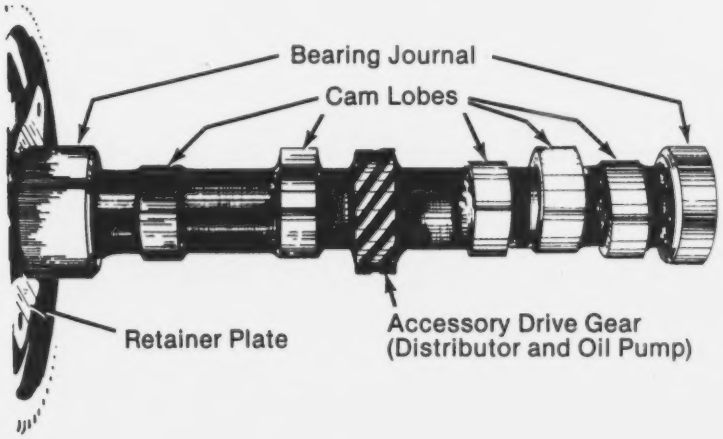
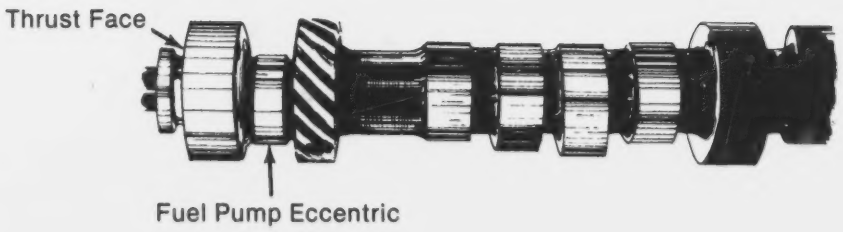


FIGURE 2



INFORMATION SHEET

V. Parts of the cam lobe (Figures 3 and 4)

FIGURE 3

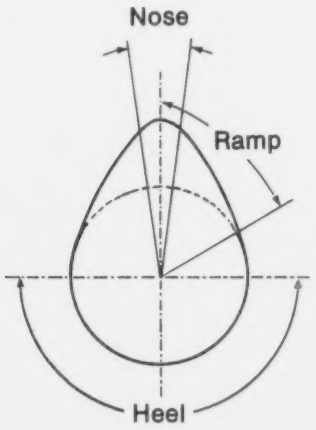
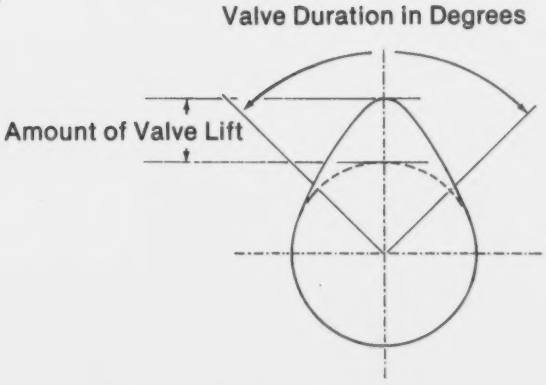


FIGURE 4



VI. Types of valve lifters

A. Solid

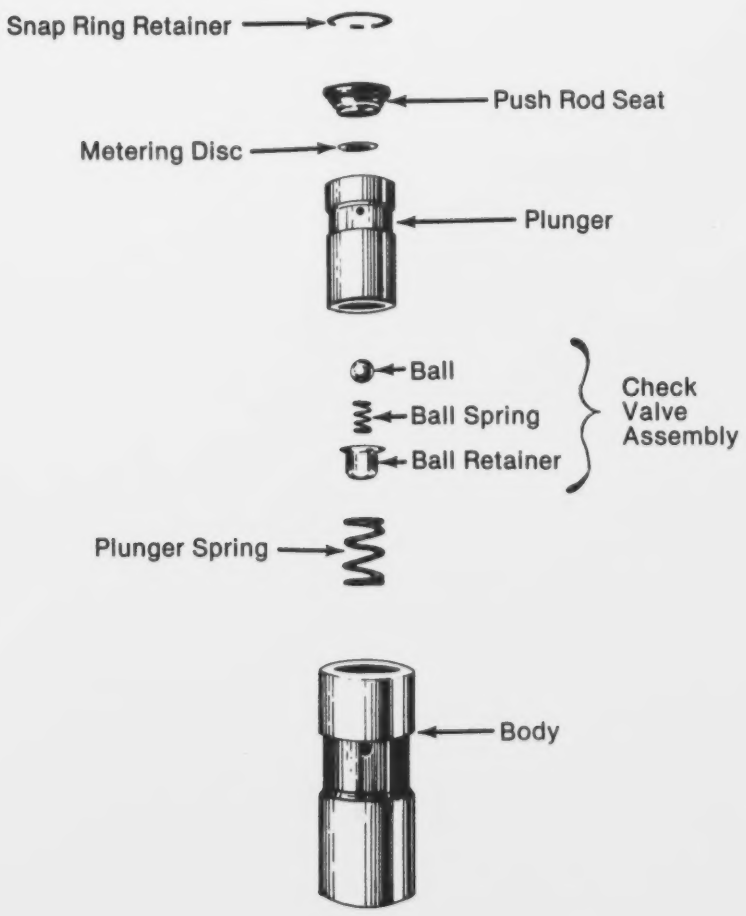
B. Hydraulic

INFORMATION SHEET

VII. Parts of hydraulic valve lifter (Figure 5)

(NOTE: Plunger and body are fitted pairs and must not be mismated.)

FIGURE 5



VIII. Operation of a hydraulic valve lifter (Transparency #3)

A. Engine oil is fed into lifter through holes in undercut area of lifter body

B. Oil under pressure inside plunger pushes check valve open and fills area between bottom of plunger and body, causing them to expand and to keep zero clearance in valve linkage when lifter is on heel portion of cam lobe

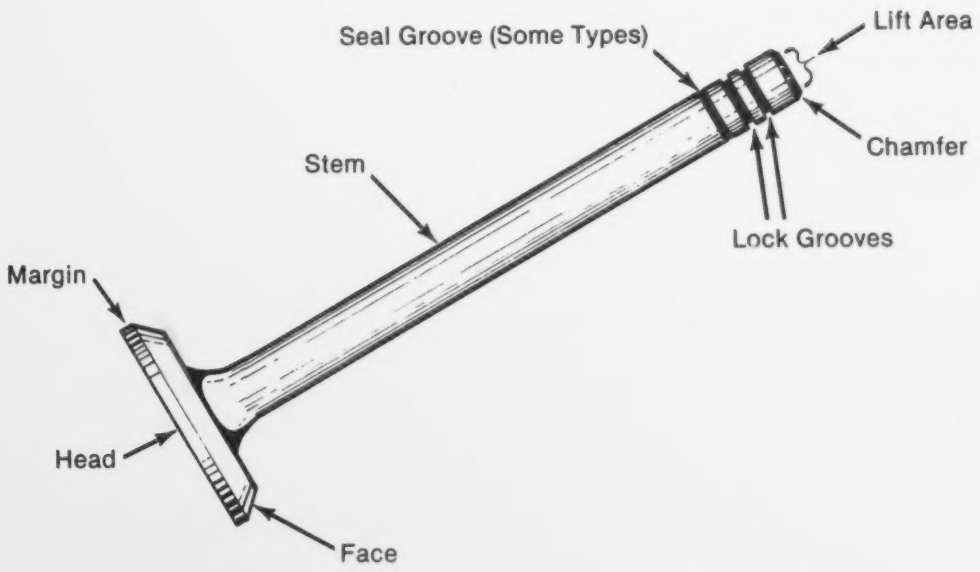
C. Oil is trapped between plunger and body to maintain plunger position in lifter body as lifter rides up cam lobe

INFORMATION SHEET

IX. Parts of a valve (Figure 6)

(NOTE: The lift area on some valves has a hardened surface that should not be machined. Removal of the hard surface would leave soft metal, which could cause the valve stem to wear very fast.)

FIGURE 6



INFORMATION SHEET

X. Parts of a valve assembly (Figures 7 and 8)

(NOTE: Some models will have an additional damper or assist spring inside the spring. Some cylinder heads contain integral valve guides that are cast as part of the head. Others contain replaceable guides that may be driven out and replaced with the aid of a driver.)

FIGURE 7

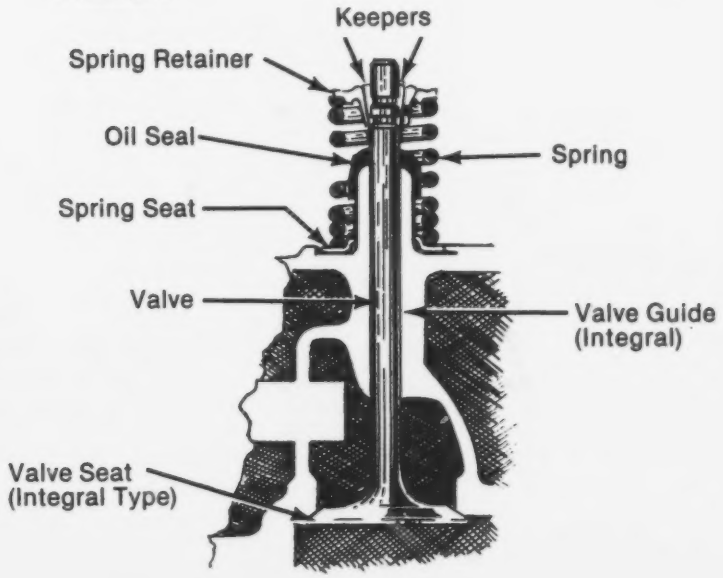
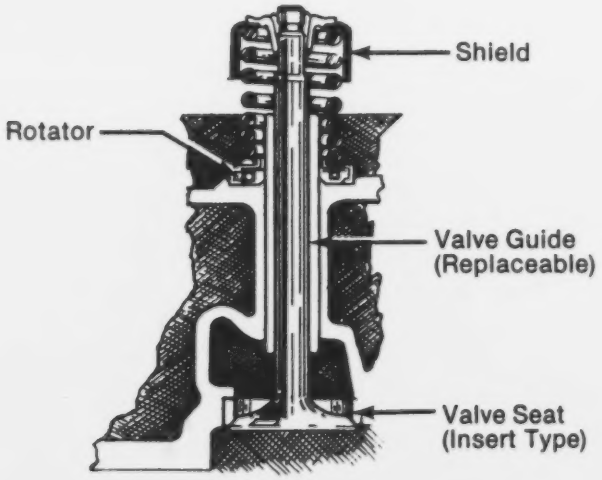


FIGURE 8



INFORMATION SHEET

XI. Types of valve springs and dampering devices (Figures 9-13)

A. Standard spring

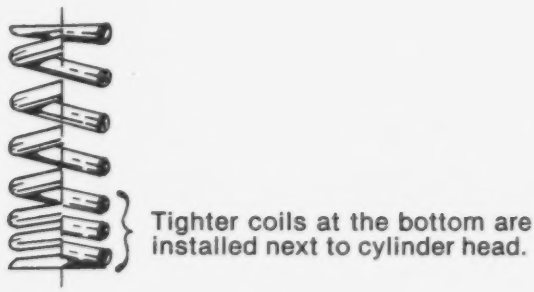
FIGURE 9

B. Standard spring with inner assist spring

FIGURE 10

C. Variable rate spring

FIGURE 11



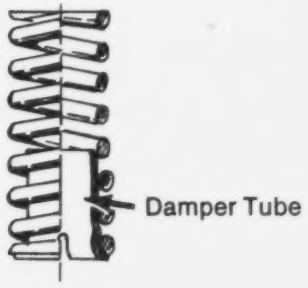
INFORMATION SHEET

D. Friction damper spring

FIGURE 12

E. Friction damper tube

FIGURE 13



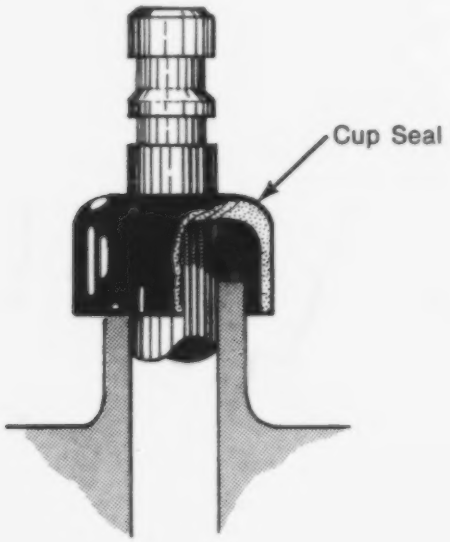
(NOTE: The variable rate spring and friction damper spring and tube are used to dampen valve spring surge. Spring surge causes the valves to float, creating a knocking noise and usually causing severe valve train wear or damage.)

INFORMATION SHEET

XII. Types of valve stem seals (Figures 14-16)

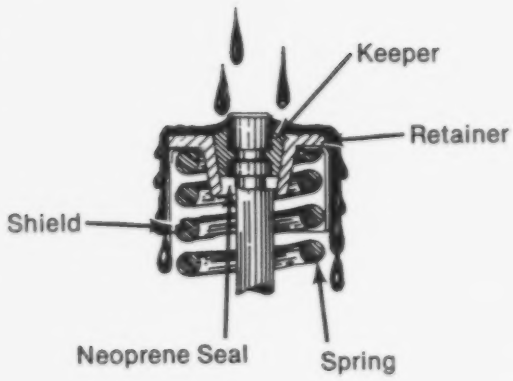
A. Cup or umbrella

FIGURE 14



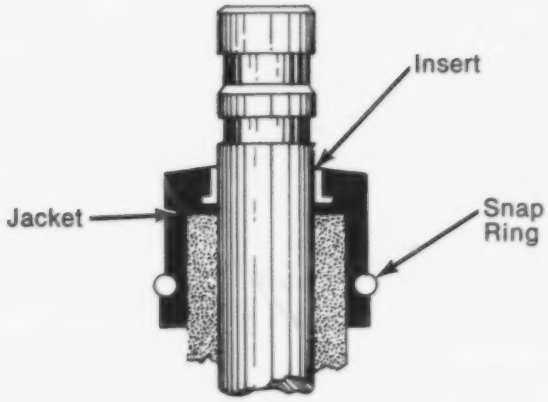
B. O-ring

FIGURE 15



C. Teflon cup

FIGURE 16



XIII. Types of valve spring keepers (Figures 17-22)

A. Pin

FIGURE 17

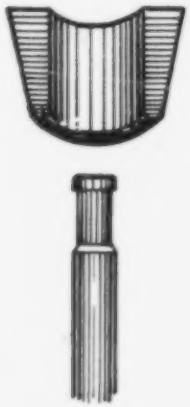
INFORMATION SHEET

B. Horseshoe

FIGURE 18

C. Plain conical

FIGURE 19



D. Single-groove conical

FIGURE 20

E. Two-groove conical

(NOTE: Single-groove and two-groove conical valve keepers are the most common types.)

FIGURE 21

INFORMATION SHEET

F. Four-groove conical

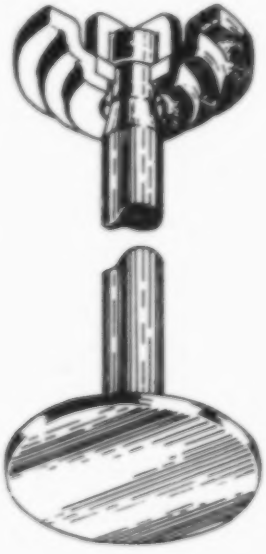
FIGURE 22

XIV. Types of valve rotators (Figures 23-25)

A. Free

(NOTE: The rocker arm exerts pressure on a valve tip cap, which exerts pressure on the spring retainer, leaving the valve free to move on the horseshoe-type keeper. The engine vibration causes the valve to rotate slightly while the valve is open.)

FIGURE 23

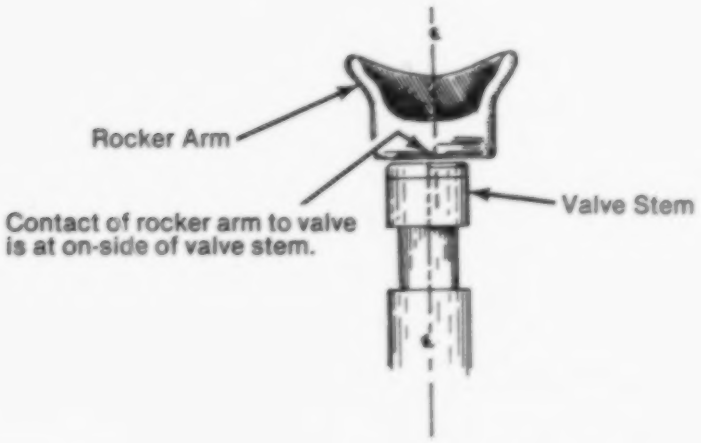


INFORMATION SHEET

B. Off-center

(NOTE: The rocker arm offsets slightly from the center line of the valve. As the valve is opened, there will be a push on the stem. The off-center push tends to make the valve rotate. This is the most common type of valve rotation.)

FIGURE 24

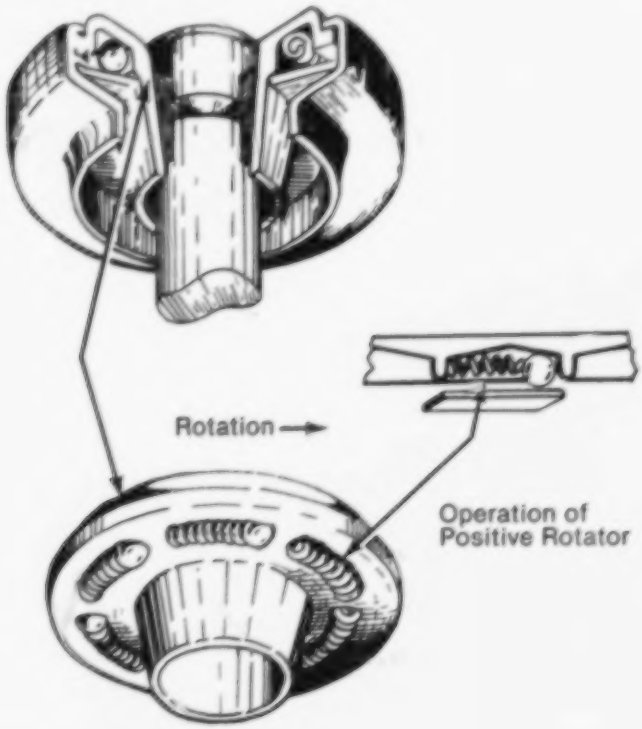


INFORMATION SHEET

C. Positive

(NOTE: The rocker arm exerts a force against the valve stem. The spring retainer portion of the rotator transfers the force through the spring collar through a group of spring-loaded balls that ride on a tapered raceway on the spring retainer. This force causes the spring to rotate as the balls roll up the tapered raceway, thus rotating the valve.)

FIGURE 25



XV. Reasons valves must seat properly

A. To make an airtight seal on the combustion chamber

B. To enable the valve to cool

XVI. Major causes of valve burning

(NOTE: The following are the major causes of valve burning, but there may be other causes.)

A. Valve not seating properly

B. Valve guides worn

INFORMATION SHEET

C. Exhaust heat riser valve stuck in closed position

D. Water jacket clogged or distribution tube causing localized hot spots

E. Valve seat warped from improper torquing of cylinder head

F. Valve springs weak or cocked

G. Valve tappet clearance insufficient

H. Engine overheating

I. Air/fuel mixture extremely lean

J. Preignition and detonation

K. Combustion chamber having carbon deposits

XVII. Tools used to recondition valves (Figures 26-38)

A. Guide cleaner

FIGURE 26

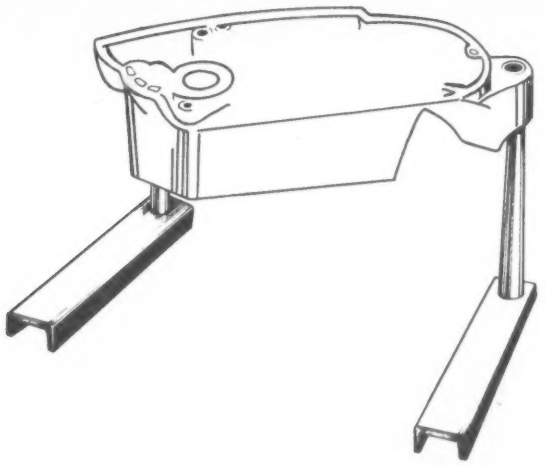
B. Guide reamer

FIGURE 27

INFORMATION SHEET

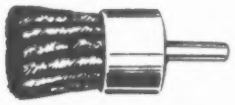
C. Cylinder head stand

FIGURE 28



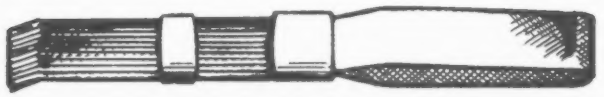
D. Carbon brush

FIGURE 29



E. Carbon scraper

FIGURE 30



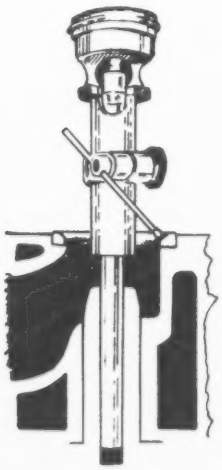
INFORMATION SHEET

F. Spring compressor

FIGURE 31

G. Valve seat indicator

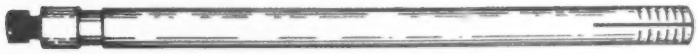
FIGURE 32



INFORMATION SHEET

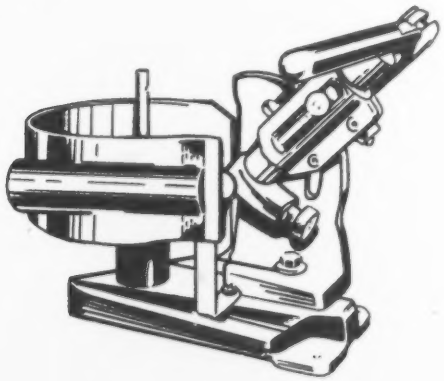
H. Seat grinding pilot

FIGURE 33



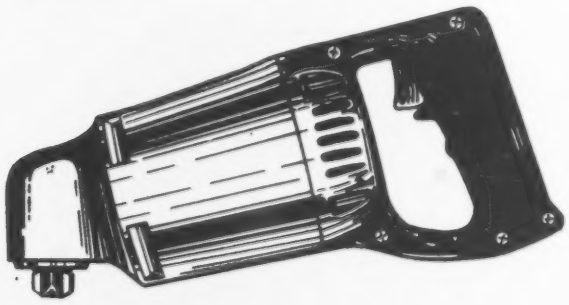
I. Wheel dressing tool (seat grinding)

FIGURE 34



J. Drive motor (seat grinding)

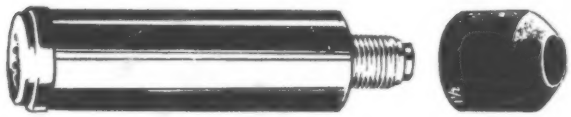
FIGURE 35



INFORMATION SHEET

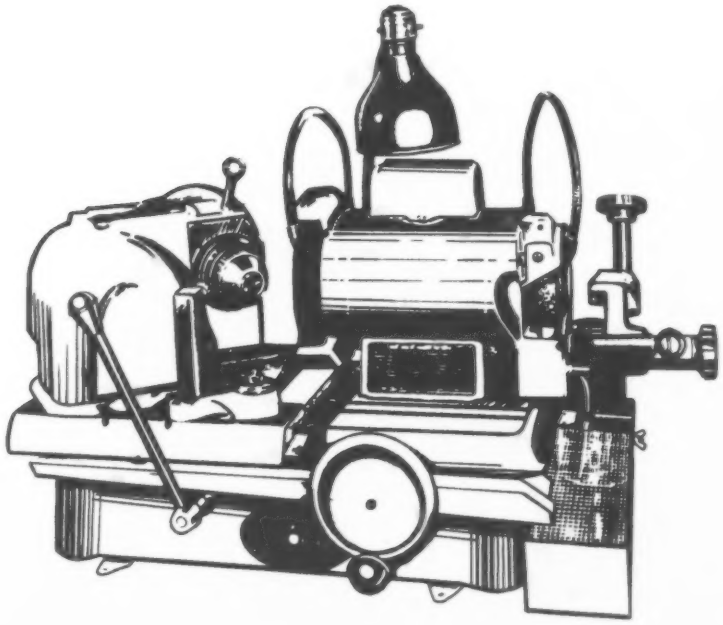
K. Wheel holder (seat grinding)

FIGURE 36



L. Valve grinding machine

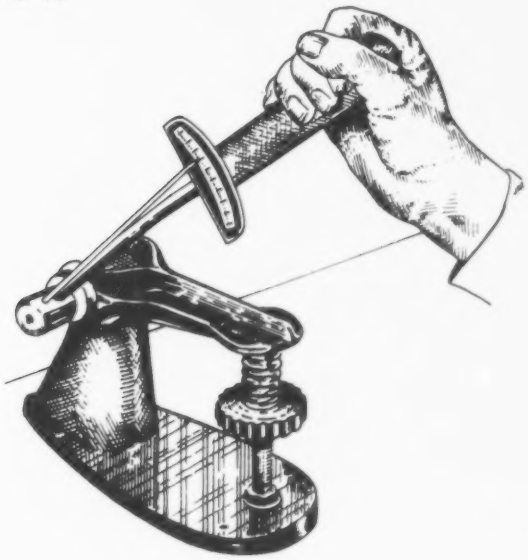
FIGURE 37



INFORMATION SHEET

M. Valve spring tension gauge

FIGURE 38

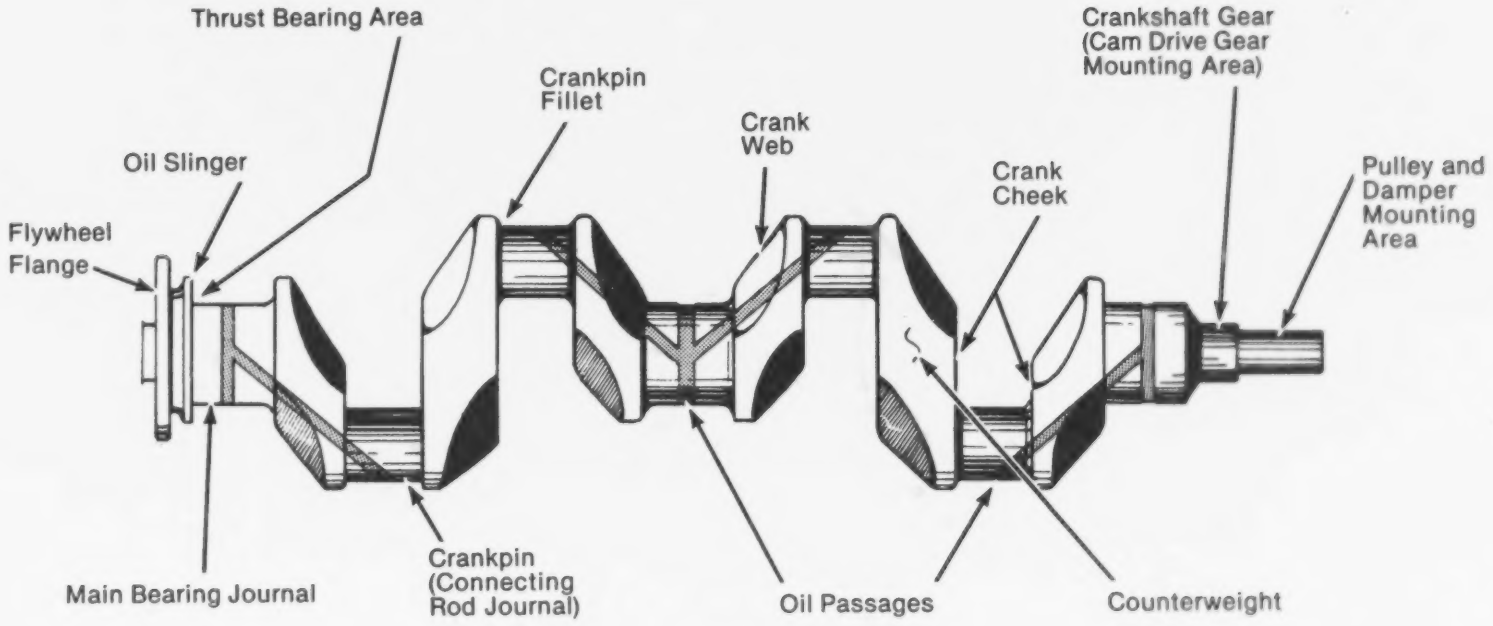


XVIII. Purpose of the crankshaft — To change reciprocating motion of the pistons to rotating motion

INFORMATION SHEET

XIX. Parts of the crankshaft (Figure 39)

FIGURE 39



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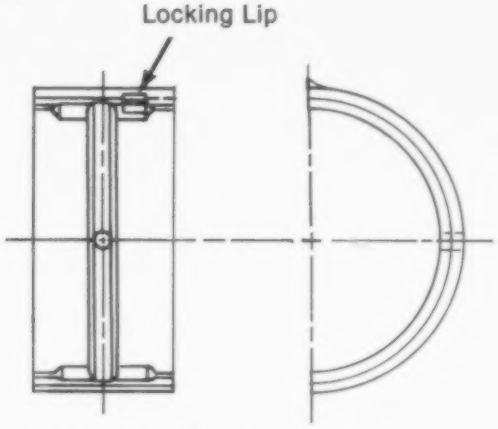
INFORMATION SHEET

XX. Types of bearings used on the cam and crankshaft (Figures 40 and 41)

A. Split sleeve friction bearings

EXAMPLES: Rod and main bearings

FIGURE 40

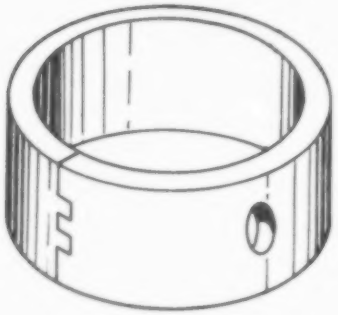


B. Sleeve friction bearing

EXAMPLE: Cam bearings

(NOTE: Sleeve friction bearings are precision-fit bearings.)

FIGURE 41



INFORMATION SHEET

XXI. Bearing spread and bearing crush (Figures 42 and 43)

A. Bearing spread

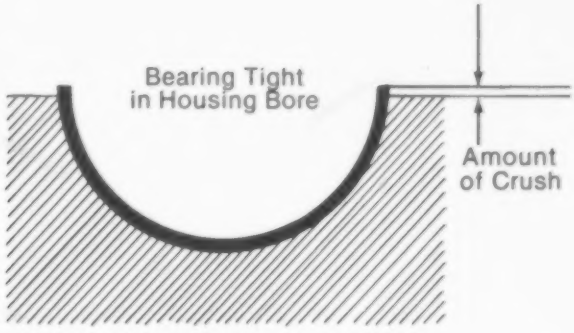
(NOTE: Bearing spread is from 0.005 to 0.020 inches wider than the housing bore. This spread helps to hold the bearing in place during installation.)

FIGURE 42

B. Bearing crush

(NOTE: Bearing crush holds the bearing in place and keeps the bearing from turning when the engine turns. Crush must exert a force of at least 12,000 psi stress between the bearing and housing bore to hold the bearing in place.)

FIGURE 43



XXII. Bearing requirements

A. Load-carrying capacity — Ability to support the severe centrifugal and combustion forces in engine

B. Embedability — Ability to permit foreign particles to become compressed into soft bearing surface to protect the smooth crankshaft

INFORMATION SHEET

C. Fatigue resistance — Resistance to severe pressure and bending without failure

D. Conformability — Ability of soft bearing surface to change to variations in shaft alignment and journal shape

E. Corrosion resistance — Ability to resist the corrosive effect of combustion by-products

F. Wear resistance — Wear rate hard and tough enough to maintain a long service life

XXIII. Action of lubrication oil in an insert-type bearing — Keeps bearing and rotating shaft journal separated by a film of oil so that there is no actual metal-to-metal contact (Transparency #4)

XXIV. Purpose of torsional vibration damper and purpose of flywheel

A. Torsional vibration damper (harmonic balancer) — Opposes crankshaft torsional vibration or twisting/untwisting action of crankshaft caused by the cylinder firing impulse

(NOTE: The vibration damper is also part of the crankshaft drive pulley assembly.)

B. Flywheel — Evens out power surges from power stroke to power stroke

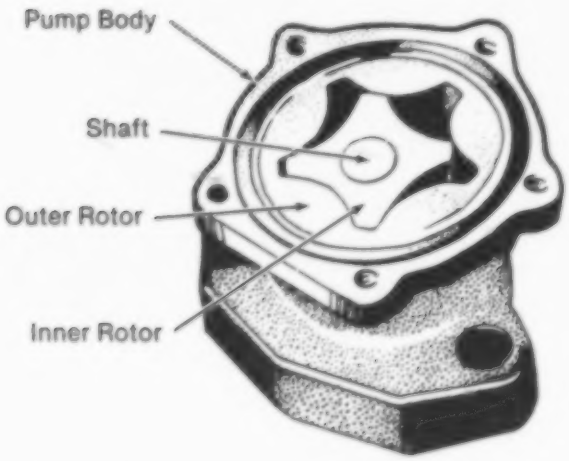
(NOTE: The flywheel also serves as part of the clutch and engine cranking system. The torque converter on automatic transmissions acts as a flywheel.)

INFORMATION SHEET

XXV. Types of oil pumps (Figures 44 and 45)

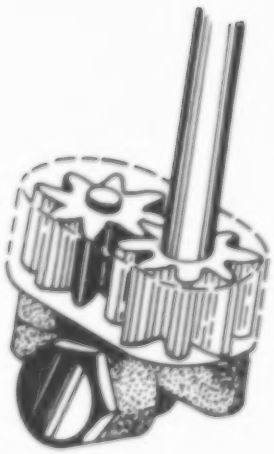
A. Rotor

FIGURE 44



B. Gear

FIGURE 45



INFORMATION SHEET

XXVI. Parts of an oil pump (Figures 46 and 47)

(NOTE: Some models require a gasket between the pump body and the pump cover.)

FIGURE 46

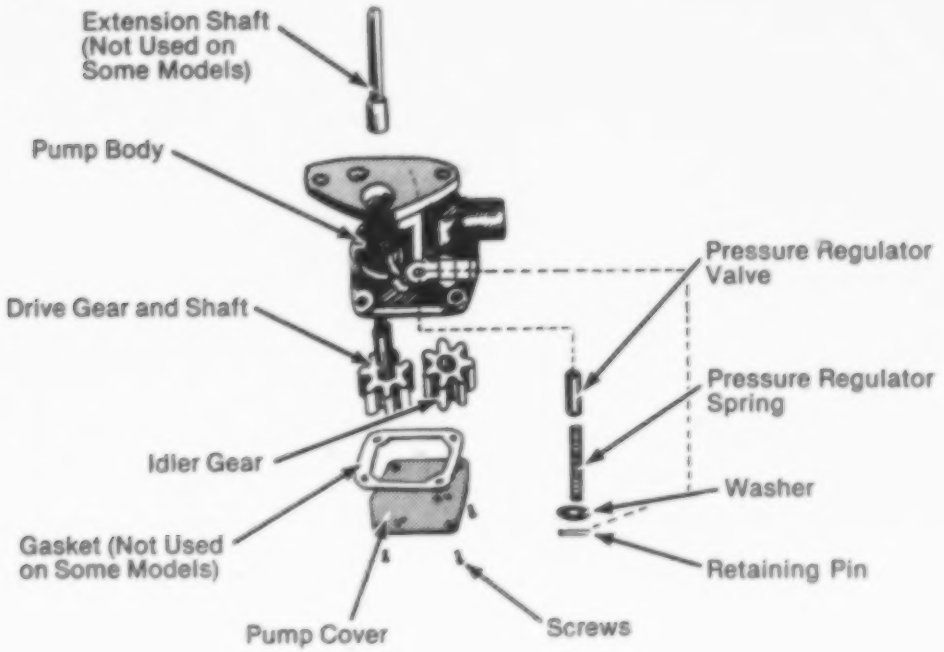
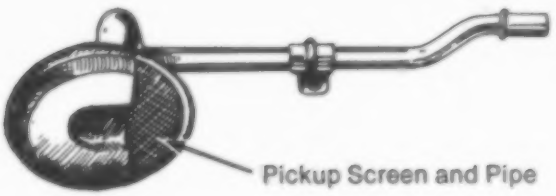


FIGURE 47

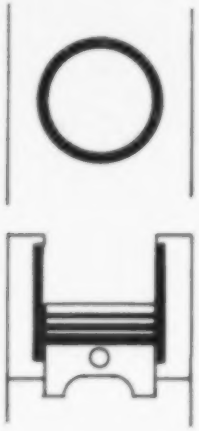


INFORMATION SHEET

XXVII. Cylinder wear patterns (Figures 48-50; Transparency #5)

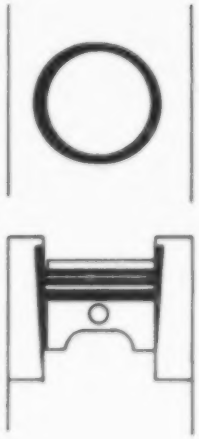
A. Normal wear

FIGURE 48



B. Taper

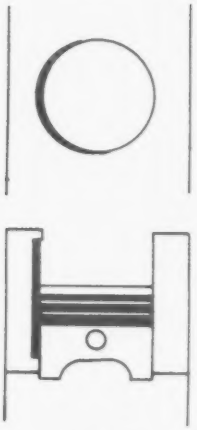
FIGURE 49



INFORMATION SHEET

C. Out-of-round

FIGURE 50



XXVIII. Methods of reconditioning cylinders (Transparency #6)

A. Honing

B. Boring

C. Replacing sleeve

XXIX. Types of cylinder sleeves (Transparency #7)

A. Dry

(NOTE: A dry sleeve is fitted inside the cylinder bore with a press fit. Engine coolant does not contact the sleeve.)

B. Wet

(NOTE: The wet sleeve is fitted into a specially prepared block. The sleeve forms the cylinder in the block and is sealed at the top and bottom to prevent coolant from leaking.)

INFORMATION SHEET

XXX. Parts of the cylinder block (Figures 51 and 52)

FIGURE 51

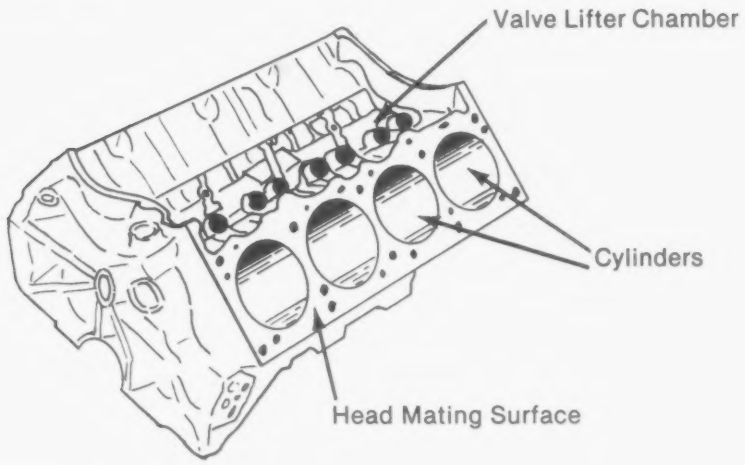
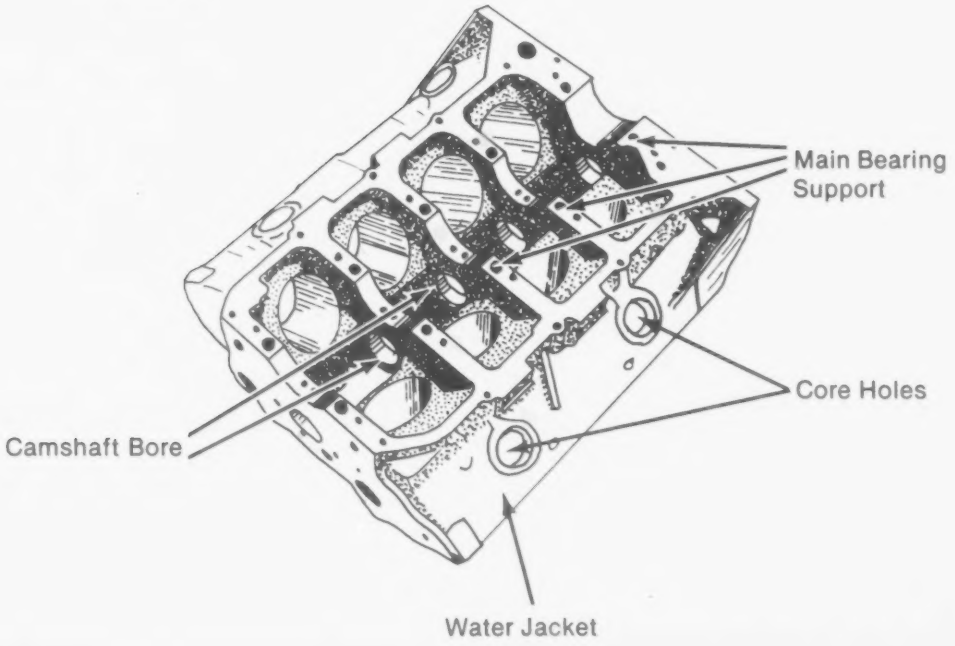


FIGURE 52



INFORMATION SHEET

XXXI. Types of cylinder block core hole plugs (Transparency #8)

A. Cup

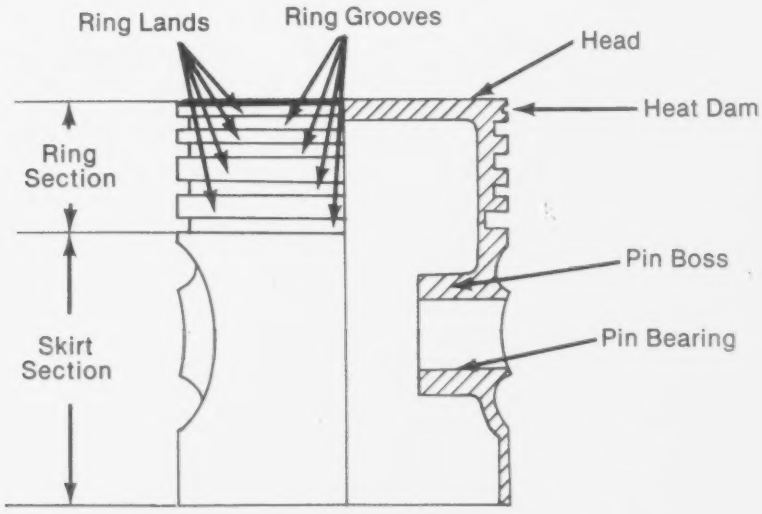
B. Expansion cup

C. Expansion disc

XXXII. Parts of a piston and connecting rod assembly (Figures 53 and 54)

A. Piston

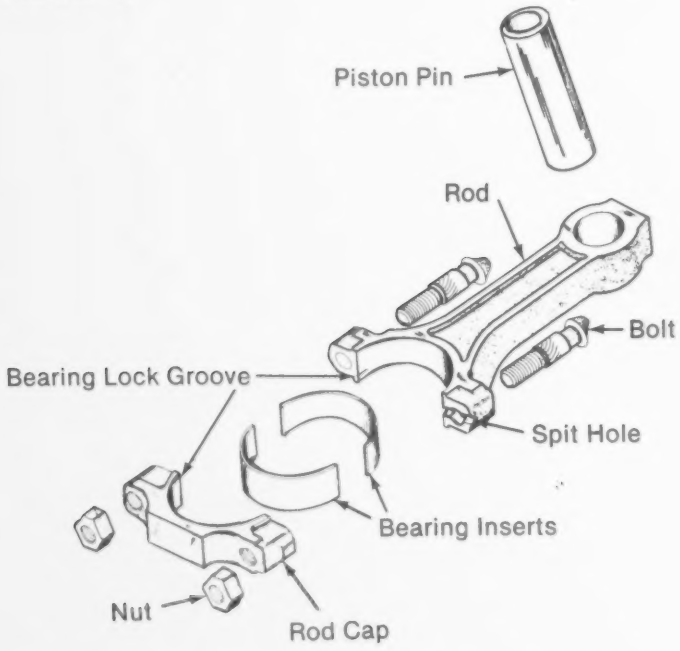
FIGURE 53



INFORMATION SHEET

B. Connecting rod assembly

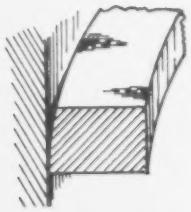
FIGURE 54



XXXIII. Types of compression rings (Figures 55-60)

A. Tapered

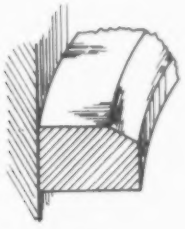
FIGURE 55



INFORMATION SHEET

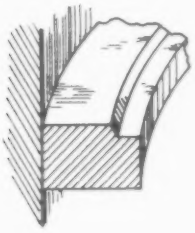
B. Chamfered

FIGURE 56



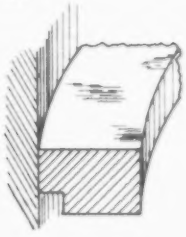
C. Counterbored

FIGURE 57



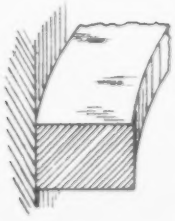
D. Scraper

FIGURE 58



E. Plain

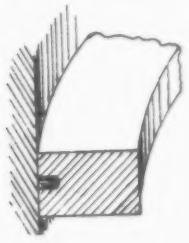
FIGURE 59



INFORMATION SHEET

F. Center grooved

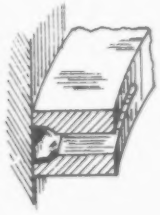
FIGURE 60



XXXIV. Types of oil rings (Figures 61-65)

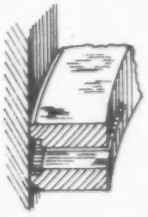
A. Radius slotted

FIGURE 61



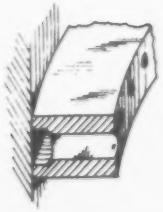
B. Wedge slotted

FIGURE 62



C. Drilled

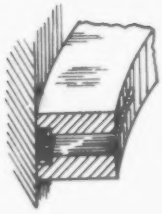
FIGURE 63



INFORMATION SHEET

D. Slotted

FIGURE 64



E. Three-piece

(NOTE: The three-piece oil ring is the most common ring used.)

FIGURE 65

XXXV. Methods of piston heat and expansion control (Transparency #9)

A. Heat dam — Groove around top of piston reduces flow of heat from piston head to piston skirt

B. Horizontal or vertical slot in piston skirt — T-shaped slot breaks path of heat traveling to skirt and allows for skirt expansion without increasing diameter

C. Cam-ground piston — Piston skirt is ground to a cam shape and contacts only in center when it is cold; as it heats up, it becomes round to fit cylinder more completely

D. Steel band or belt — Steel band cast into piston pin boss reduces expansion of piston skirt due to heat, and conducts heat out through pin boss

XXXVI. Piston conditions and related causes (Transparencies #10-#!2)

A. Cracked piston skirt — Piston improperly fitted to cylinder

B. Moderate and severe skirt damage — Cylinder detonation

C. Piston head damage — Preignition or overheated cylinder

INFORMATION SHEET

D. Piston skirt wear — Misaligned connecting rod

E. Piston pin boss and ring land damage — Loose or broken piston pin lock ring

F. Piston rings stuck in groove — Excessive carbon deposit buildup

G. Ring land damage — Broken piston ring and preignition

H. Excessively worn upper ring groove — Poor maintenance, poor air filtration, or service abuse

XXXVII. Methods of lubricating cylinder walls and piston pins (Transparency #13)

A. Splash system

B. Spit oil hole in rod

C. V-groove in rod

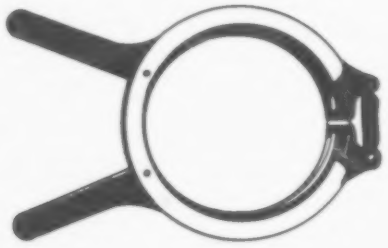
XXXVIII. Tools and equipment used to recondition cylinders and pistons (Figures 66-75)

A. Cylinder gauge

FIGURE 66

B. Ring expander

FIGURE 67



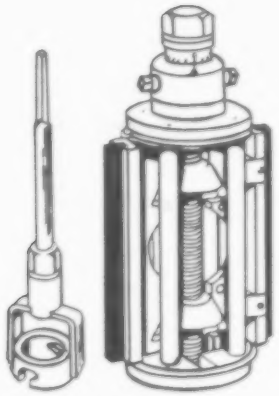
INFORMATION SHEET

C. Ring compressor

FIGURE 68

D. Boring hone

FIGURE 69



E. Glaze-breaker hone

FIGURE 70

INFORMATION SHEET

F. Piston pin press

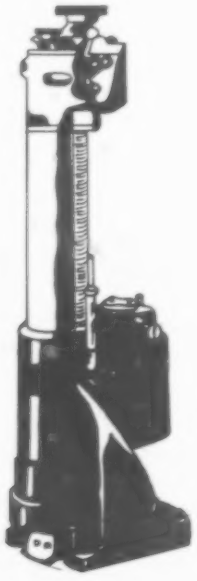
FIGURE 71

G. Sleeve puller and press

FIGURE 72

H. Boring bar

FIGURE 73



INFORMATION SHEET

I. Piston gauge and scale

FIGURE 74

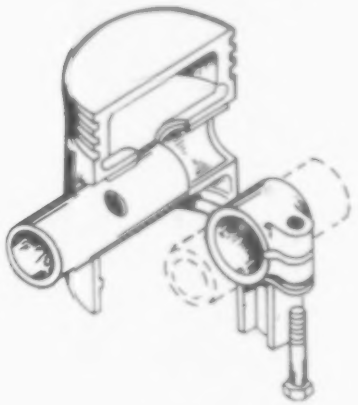
J. Ring groove gauge

FIGURE 75

XXXIX. Types of piston pin locks (Figures 76-79)

A. Locked to connecting rod

FIGURE 76



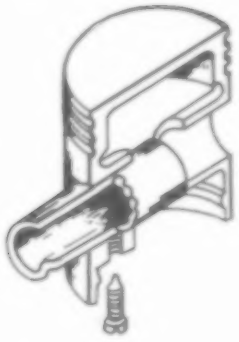
INFORMATION SHEET

B. Free floating

FIGURE 77

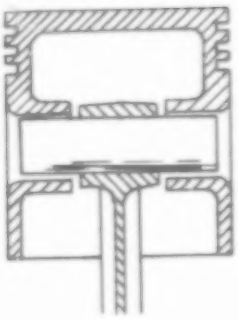
C. Locked to piston

FIGURE 78

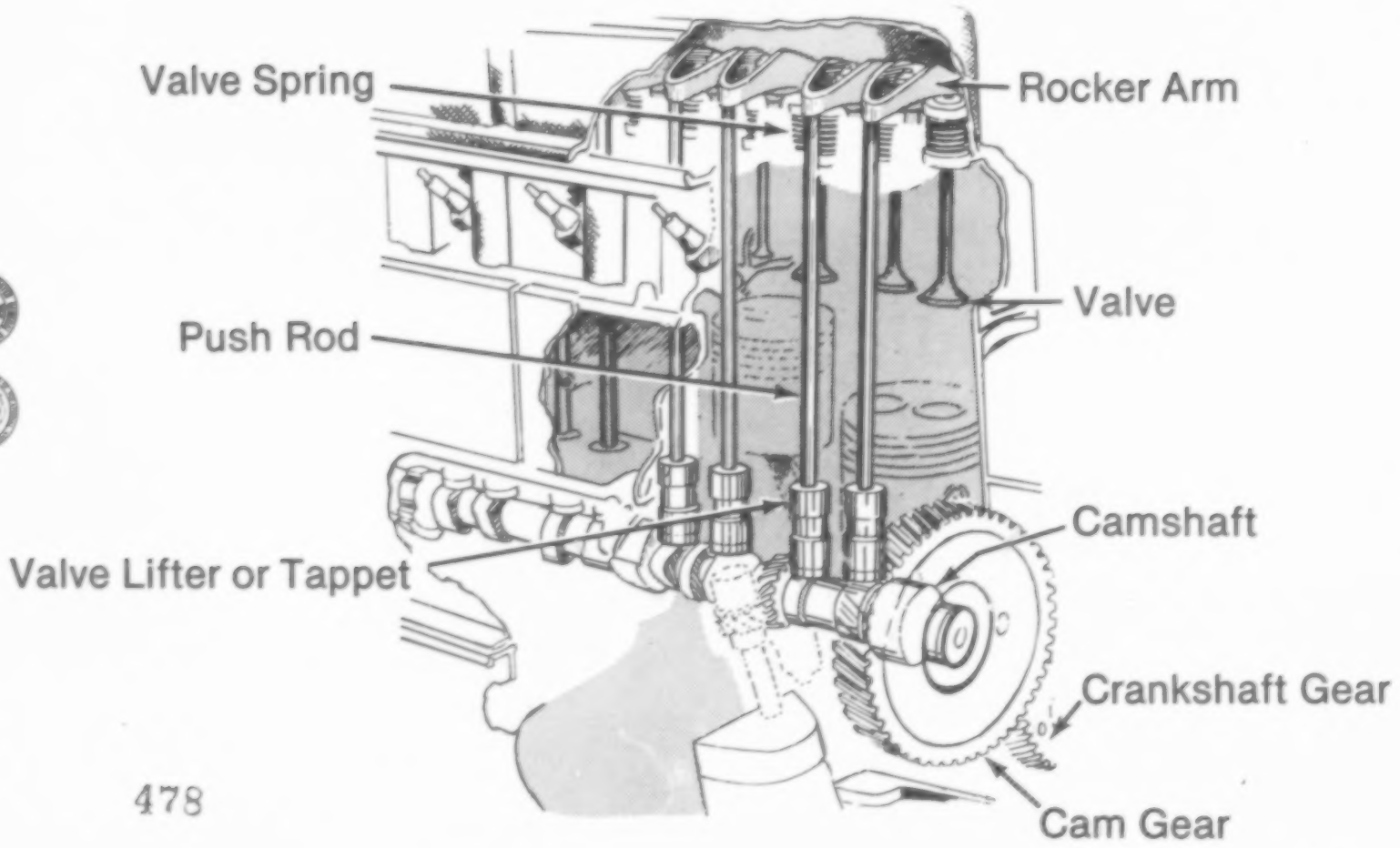


D. Press fit in rod

FIGURE 79



Parts of the Valve Train



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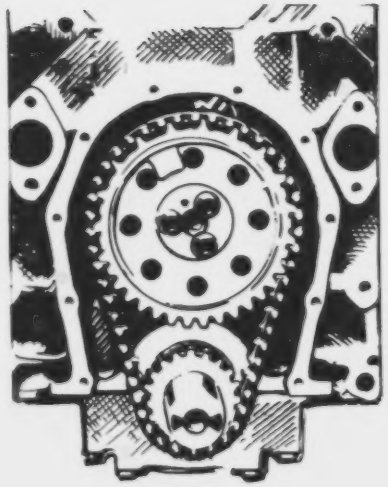
TM #1

HEM - 177-B

Methods of Driving the Camshaft

Chain



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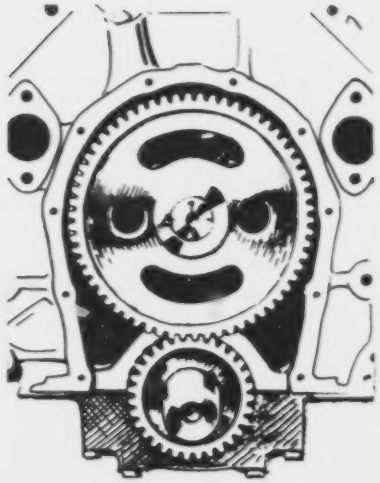
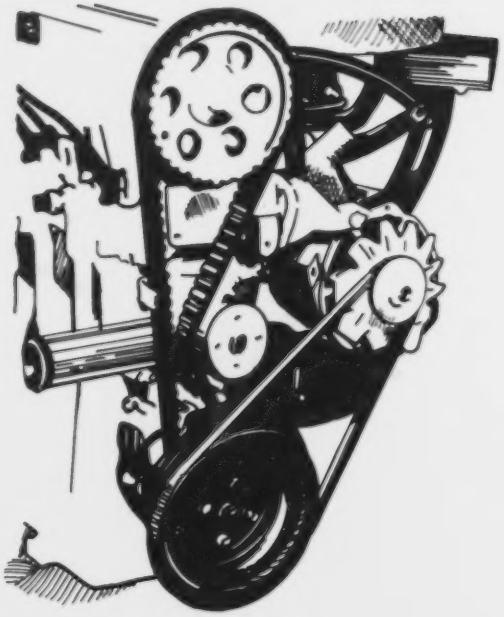
Gear



Belt



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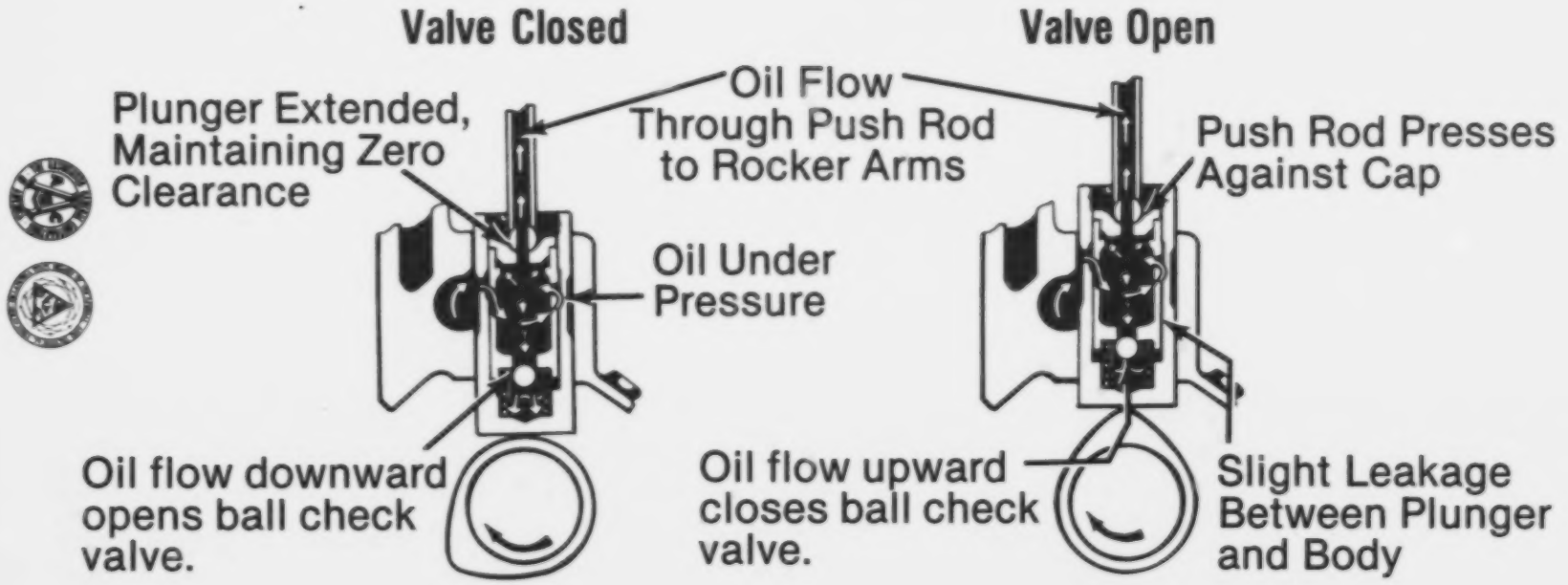
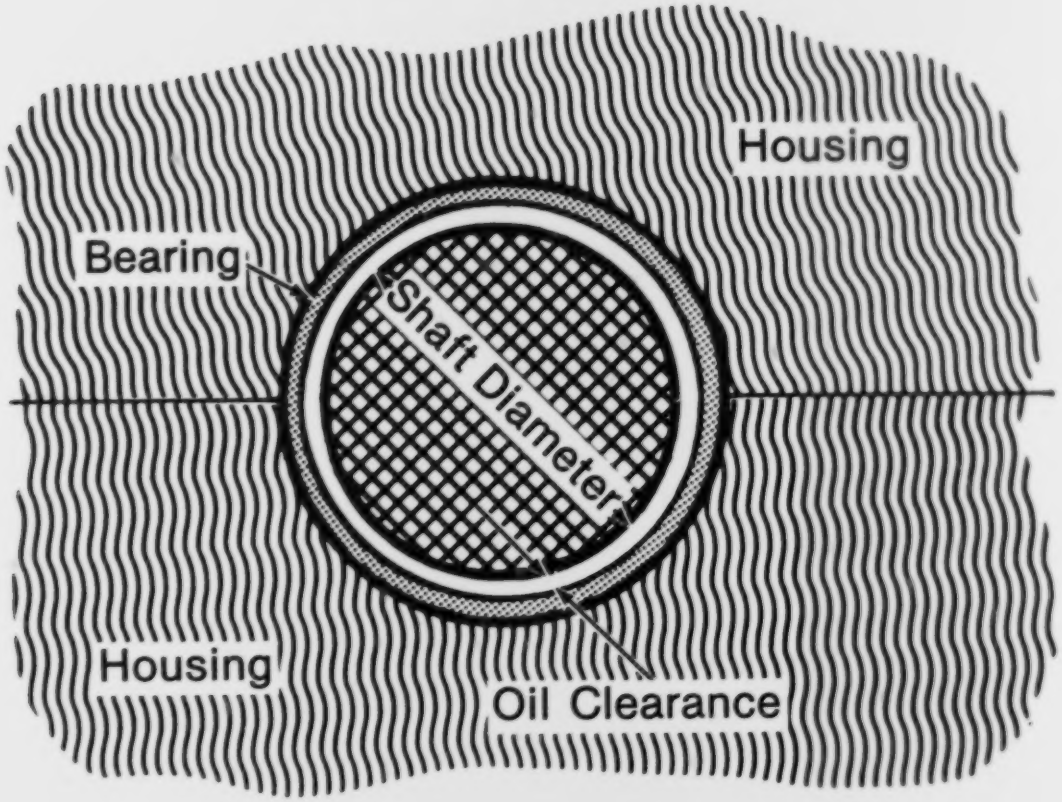
Operation of a Hydraulic Valve Lifter


Valve Closed
Valve Open
Plunger Extended, Maintaining Zero Clearance
Oil Flow Through Push Rod to Rocker Arms
Push Rod Presses Against Cap
Oil Under Pressure
Oil flow downward opens ball check valve.
Oil flow upward closes ball check valve.
Slight Leakage Between Plunger and Body

Lubricating Oil Action in an Insert Bearing



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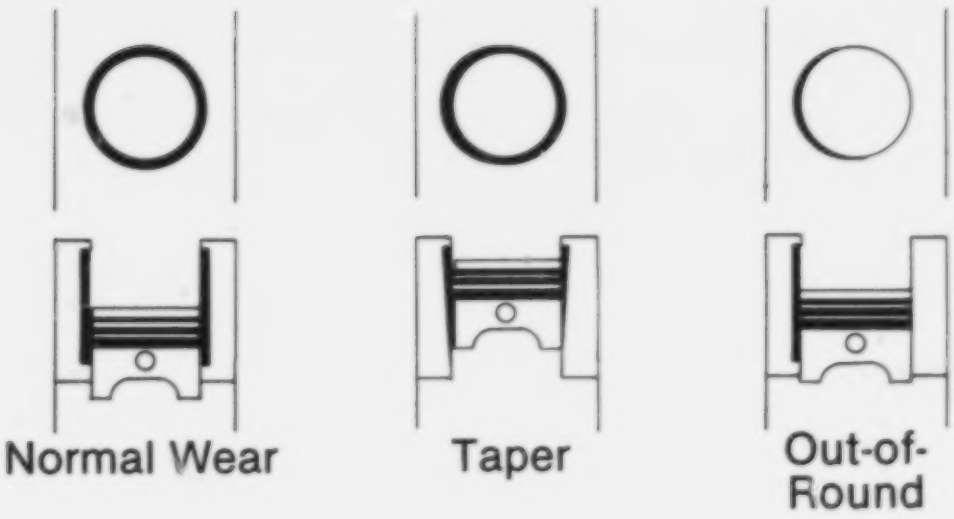
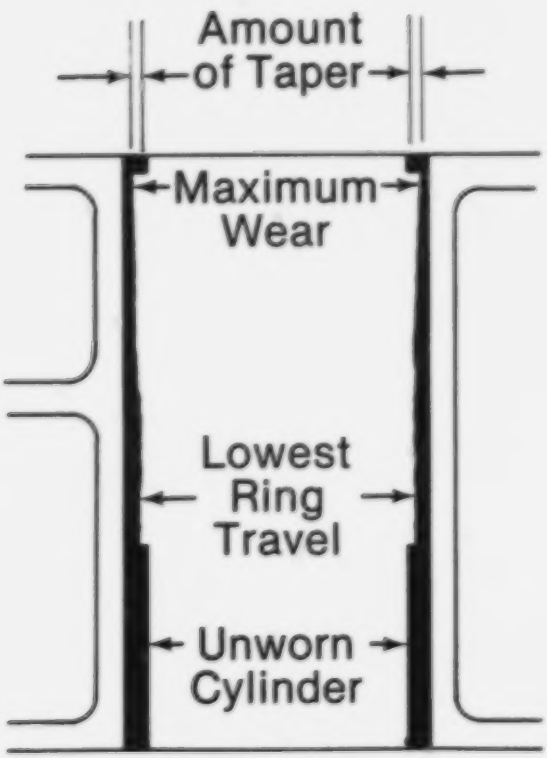
TM #4

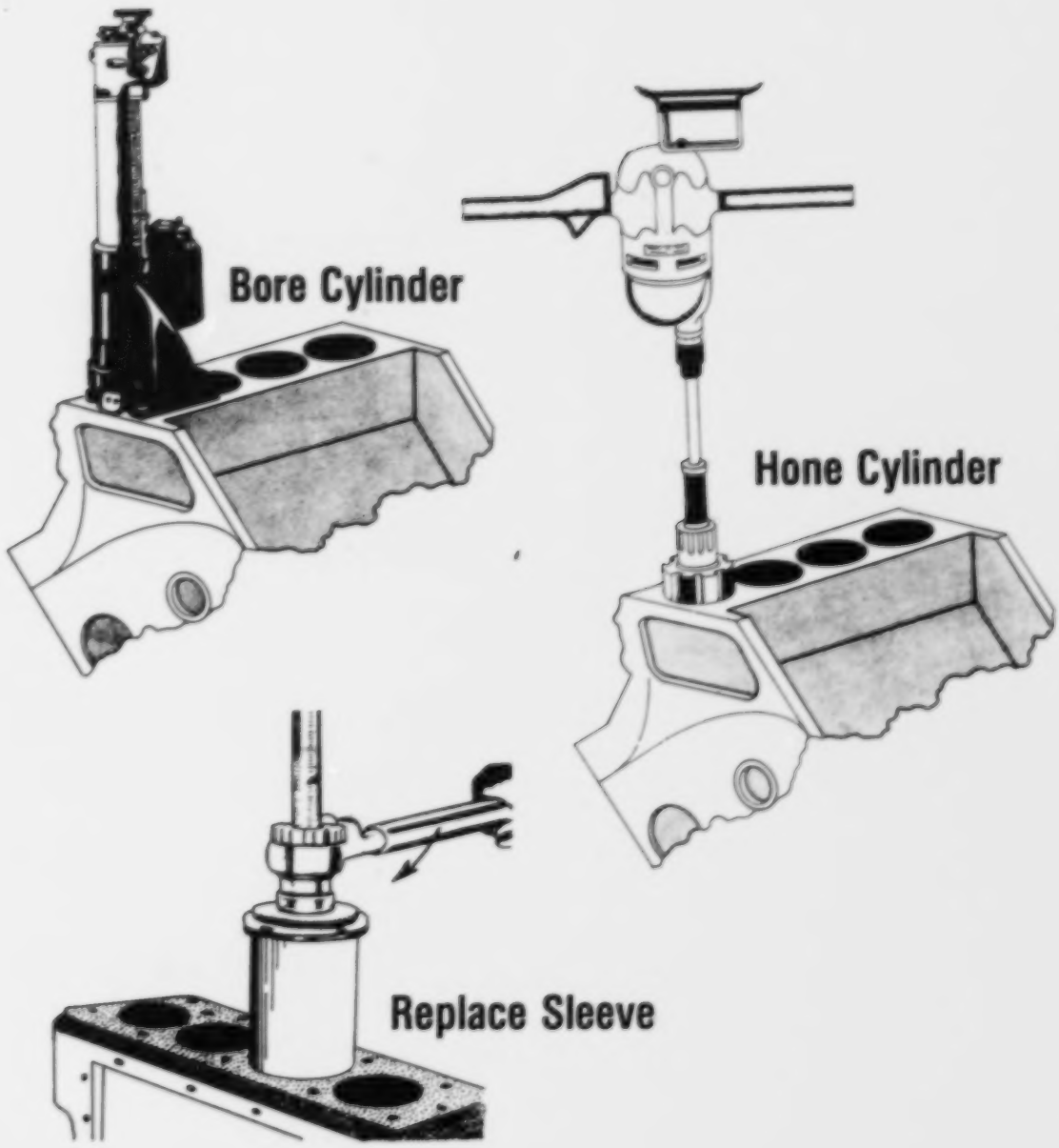
HEM - 183-B

Cylinder Wear Patterns

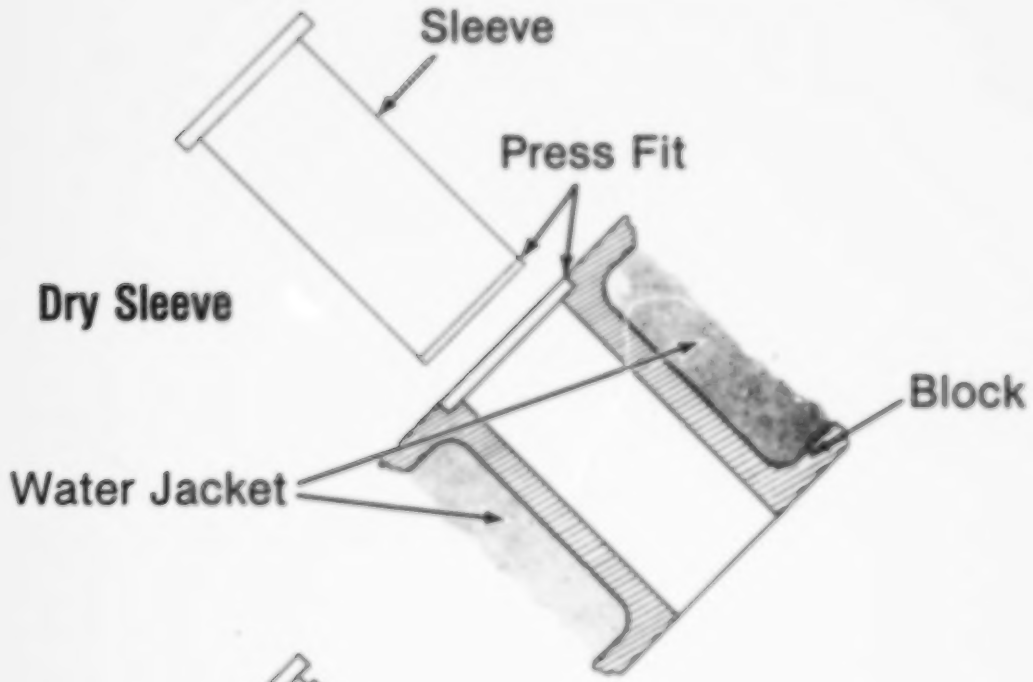


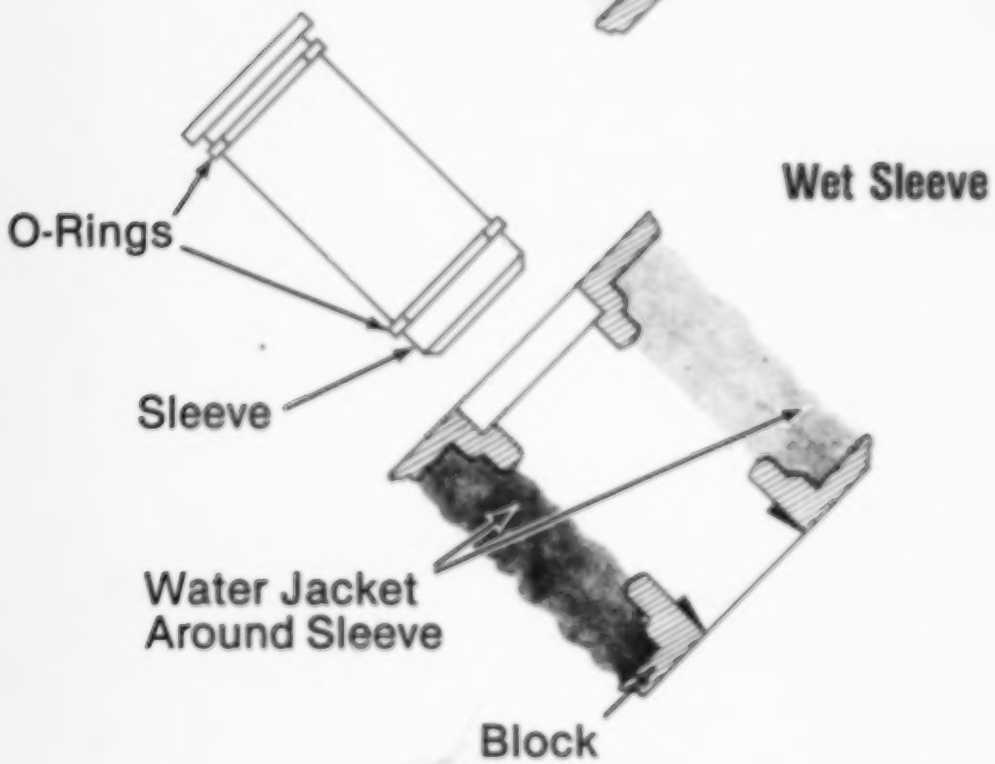


Methods of Reconditioning Cylinders

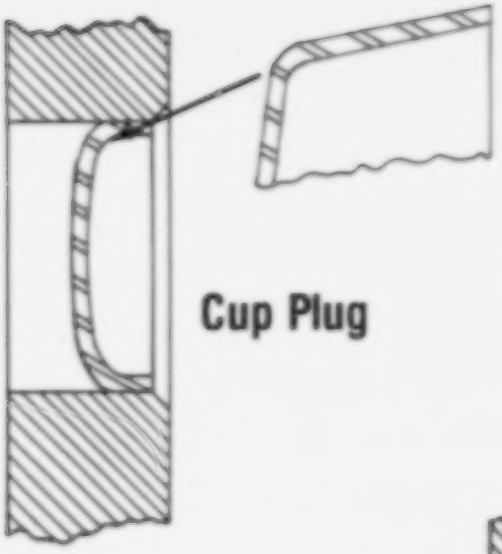


Types of Cylinder Sleeves

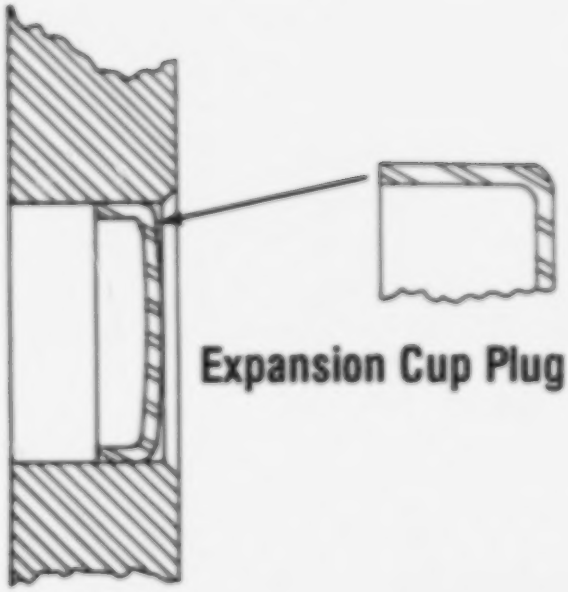




Types of Cylinder Block Core Hole Plugs



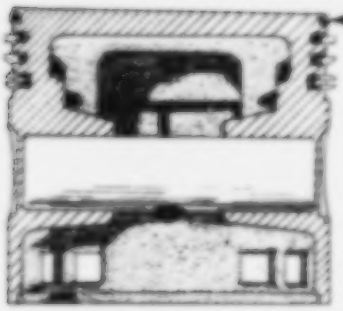
Cup Plug



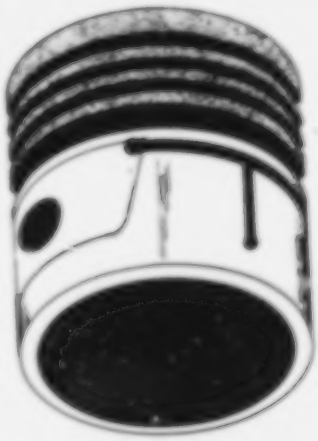
Expansion Cup Plug

Expansion Disc Plug

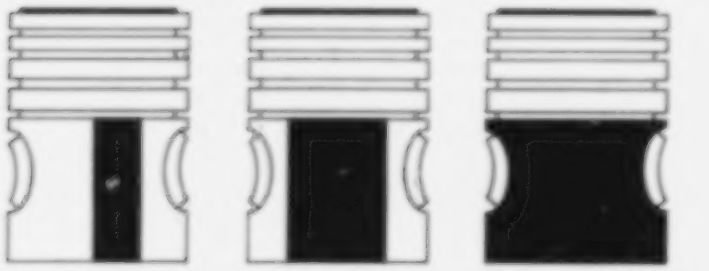
Methods of Heat and Expansion Control



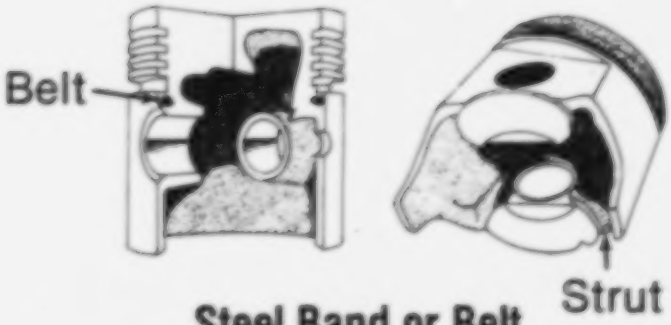
Heat Dam



Horizontal or Vertical Slot



Cam Ground Piston

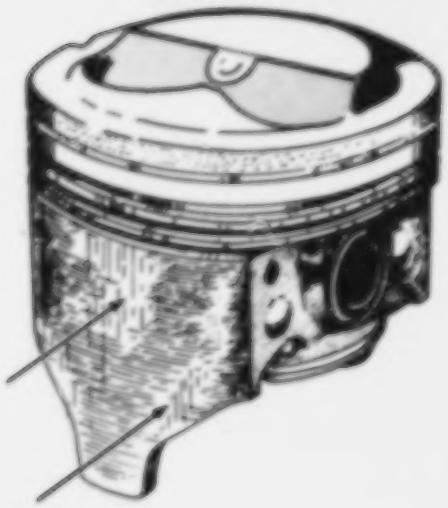


Steel Band or Belt

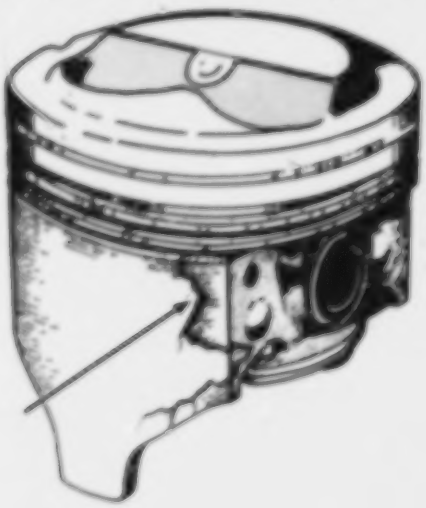
Piston Conditions and Related Causes

Piston Damage from Detonation

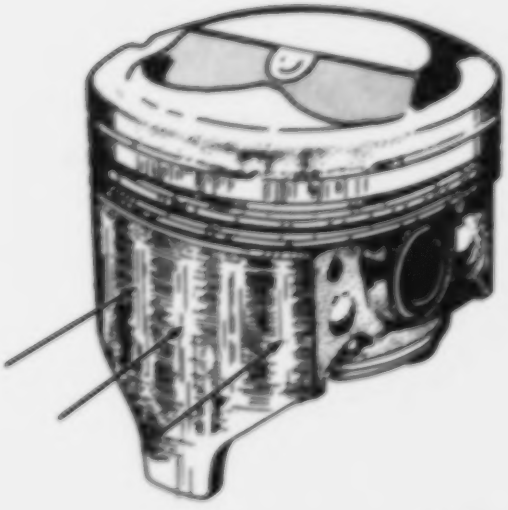
Normal Piston Skirt Wear



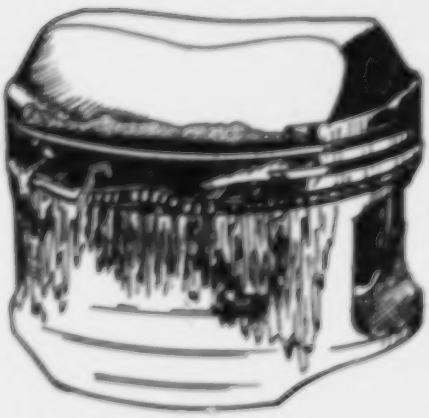
Cracked Piston Skirt



Moderate



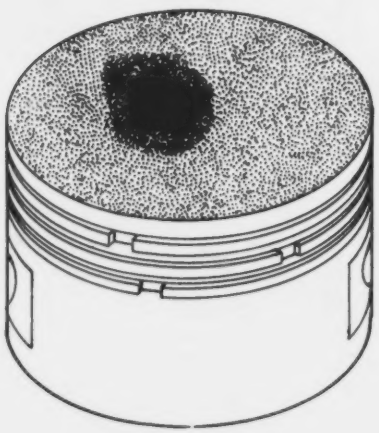
Severe



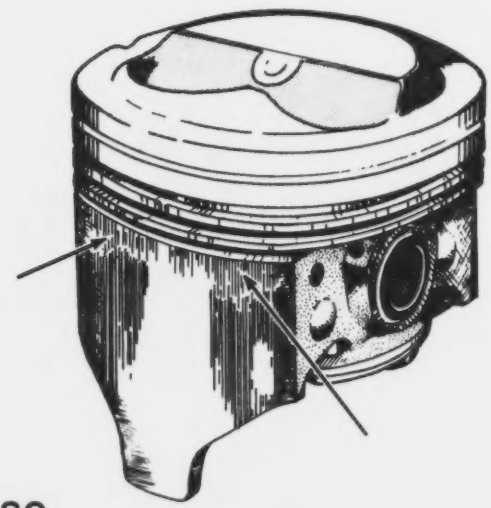
Piston Conditions and Related Causes

(Continued)

Piston Head Damage from Preignition

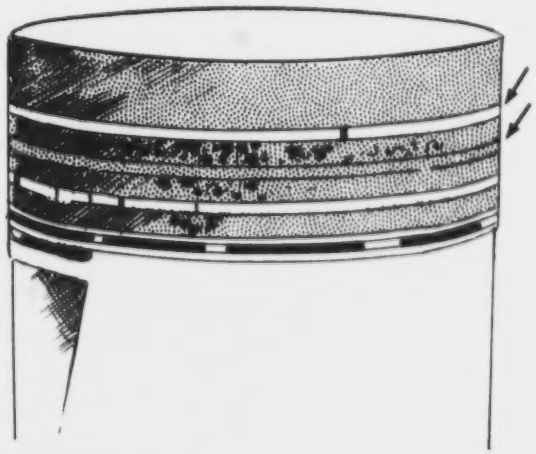


Skirt Wear Caused by a Misaligned Connecting Rod



Damage Caused by a Loose Piston Pin Lock Ring

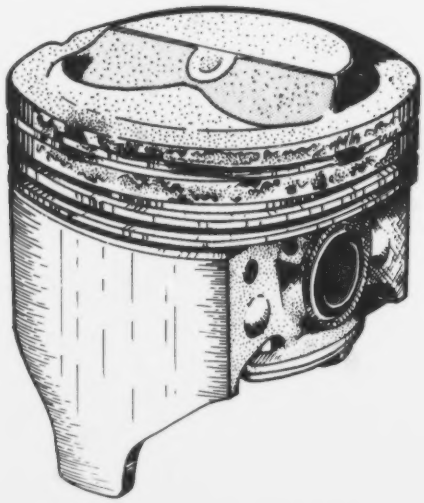
Piston Rings Stuck in Their Grooves



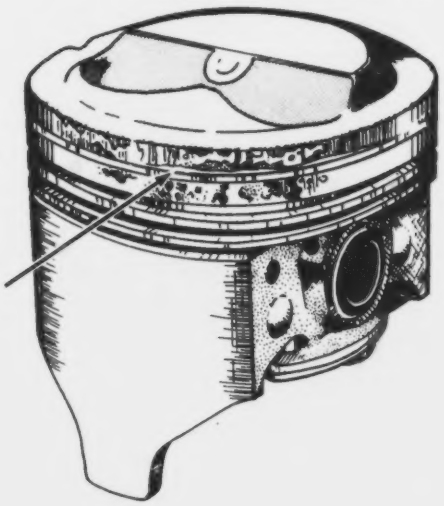
Piston Conditions and Related Causes

(Continued)

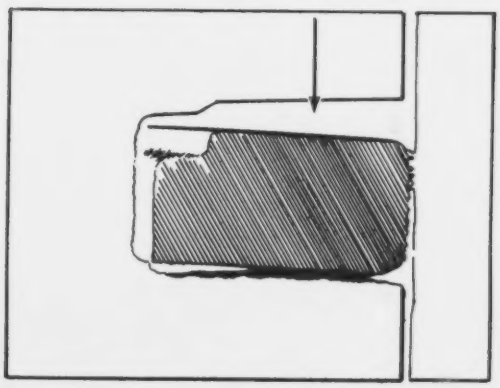
Damage Caused by a Broken Ring



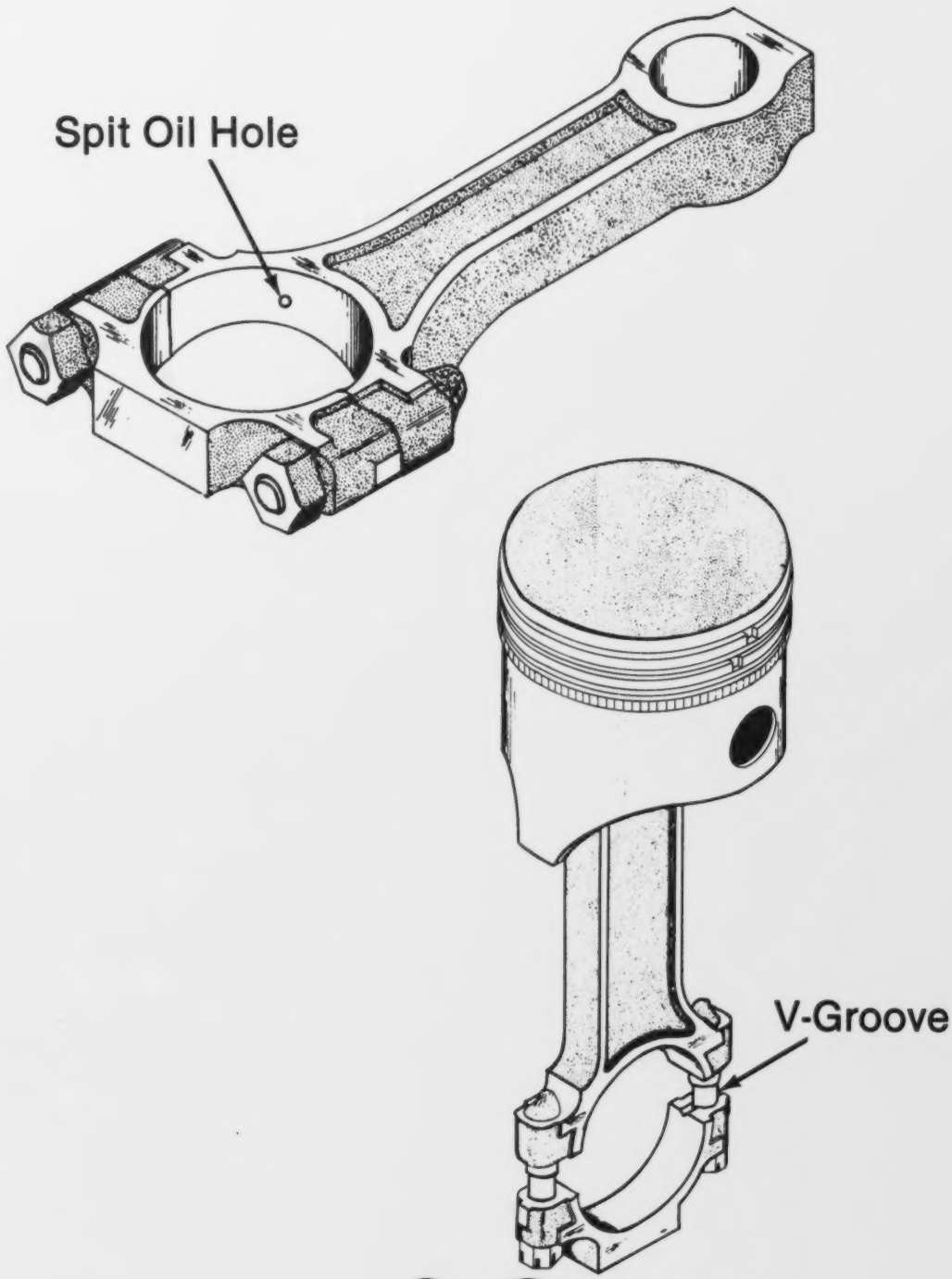
Side View of a Worn Upper Groove



Cross Section of a Worn Upper Groove



Cylinder Lubrication



CLEANING, INSPECTING, AND RECONDITIONING
GASOLINE ENGINES
UNIT III

JOB SHEET #1 — INSPECT TIMING GEARS AND MEASURE TIMING CHAIN FOR STRETCH AND CAMSHAFT END PLAY

I. Equipment and materials

- A. Basic hand-tool set
- B. Safety glasses
- C. Torque wrench
- D. 6-inch steel rule

II. Procedure

- A. Check timing chain for stretch
  1. Place rule next to timing chain so that any movement of chain may be measured (See Figure 80.)
  2. Place torque wrench and socket over camshaft bolt, and apply torque of approximately 20 foot-pounds in direction of crankshaft rotation to take up slack

     (NOTE: To measure total chain stretch, it may be necessary to block crankshaft from rotating.)
  3. Mark a reference position on timing gear and align scale with reference mark
  4. Apply torque of approximately 20 foot-pounds in reverse direction

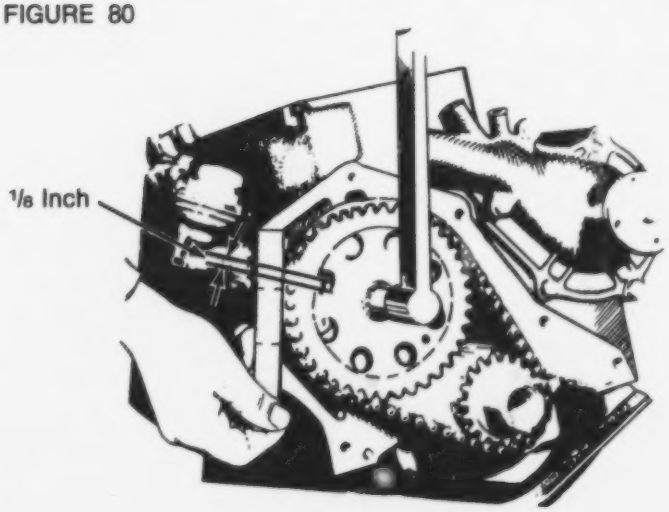
     (NOTE: Apply enough torque to take up slack in the chain but not to move the crankshaft.)

JOB SHEET #1

5. Measure chain slack (Figure 80)

(NOTE: If movement exceeds 1/8 inch, replace the timing chain.)

FIGURE 80



B. Inspect timing and crankshaft gears

1. Inspect gear teeth for chipping and grooving

2. Inspect fiber of nylon gears for cracks or flaking

(NOTE: Replace gears if any of the above conditions are present. Replace the chain and both gears as a set to obtain better performance and longer life.)

(CAUTION: Particles flaking from nylon timing gear could clog the oil pump pickup screen.)

C. Clean work area; clean and put away all tools and equipment

CLEANING, INSPECTING, AND RECONDITIONING
GASOLINE ENGINES
UNIT III

JOB SHEET #2 — INSPECT CAMSHAFT

I. Equipment and materials

A. 2 V-blocks

B. Dial indicator

C. Micrometers, 0 to 3.000-inch range

D. Appropriate service manual

II. Procedure

A. Inspect camshaft visually

1. Check journals for grooving or pitting

2. Check cam lobes for scoring, grooving, or chipping

3. Check camshaft accessory drive gear for wear or damage

4. Check fuel pump eccentric for wear or scoring if camshaft is so equipped

(NOTE: If any of the above conditions exist, replace the camshaft.)

JOB SHEET #2

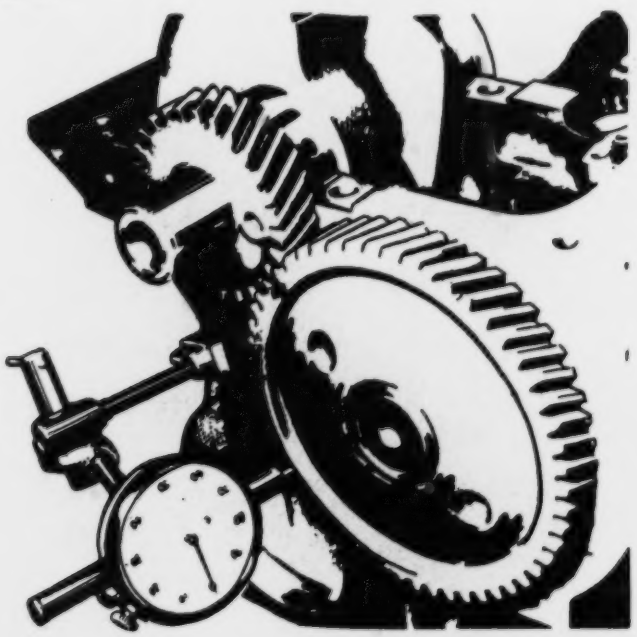
B. Measure camshaft end play

(NOTE: Camshaft end play can be measured by dial indicator or feeler gauge. The correct method to use will depend on the type of camshaft thrust plate and cam gear.)

1. Measure camshaft end play with dial indicator

a. Set up dial indicator (Figure 81)

FIGURE 81



b. Push camshaft toward cylinder block until it has bottomed

c. Adjust dial indicator contact so that it fits straight against gear edge

d. Set dial indicator to 0.000 inch

e. Pry outward on camshaft

(CAUTION: Use care to avoid damage while prying on the camshaft.)

f. Read dial indicator

JOB SHEET #2

g. Compare indicator reading to manufacturer's specifications; repair as necessary

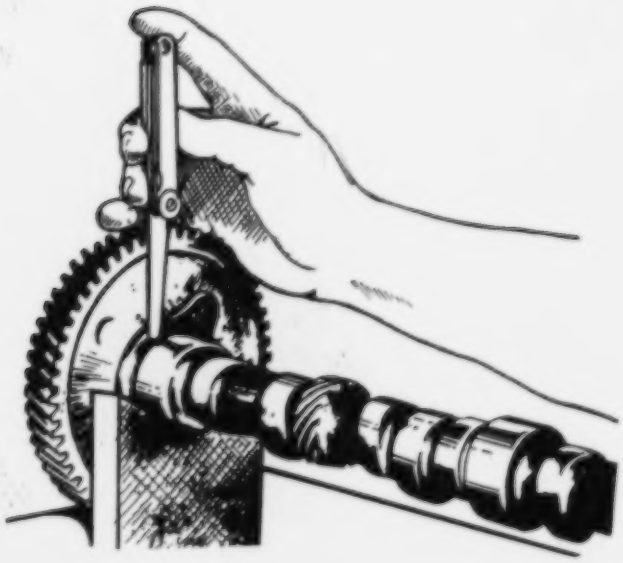
2. Measure camshaft end play with feeler gauge

a. Secure cam gear to camshaft

b. Select feeler gauge thickness that will slide between camshaft thrust plate and thrust face with a slight drag (Figure 82)

(NOTE: The thickness of the gauge is the end play of the camshaft. Compare this reading with manufacturer's specifications.)

FIGURE 82



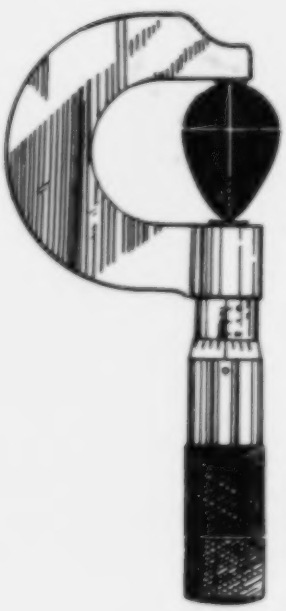
JOB SHEET #2

C. Measure camshaft lobe

1. Measure lobe height (Figure 83)

(NOTE: Lobe heights should not vary more than 0.003 inch. If they do, replace camshaft.)

FIGURE 83

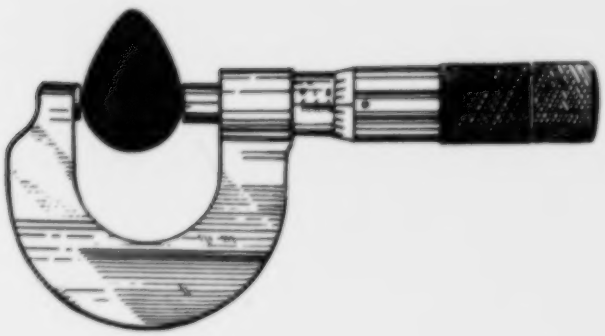


JOB SHEET #2

2. Measure heel diameter of each lobe and compare to determine wear (Figure 84)

(NOTE: Lobe heel diameter should not vary more than 0.001 inch.)

FIGURE 84

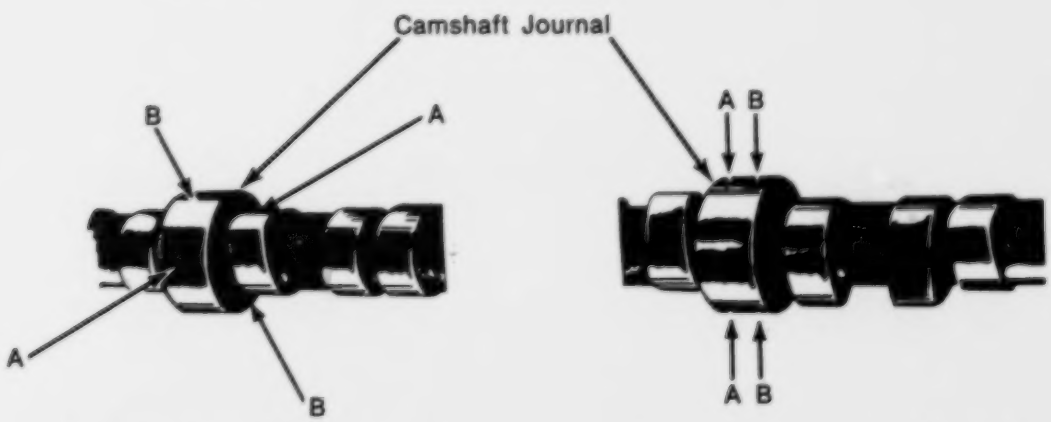


D. Measure camshaft journals (Figure 85)

1. Check each journal for out-of-round condition
2. Check each journal for taper

(NOTE: Journal out-of-round or taper should not exceed 0.001 inch.)

FIGURE 85



Compare measurements A and B for out-of-round condition.

Compare measurements A and B for journal taper condition.

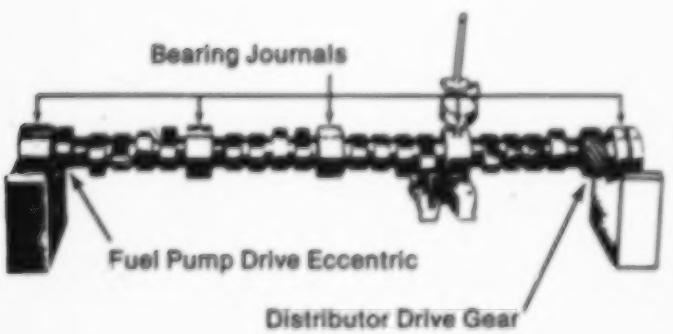
JOB SHEET #2

E. Check camshaft runout (Figure 86)

1. Place camshaft on V-block so that shaft is supported by end bearing journals
2. Position dial indicator so that it contacts bearing journal squarely
3. Rotate shaft to locate position of lowest reading
4. Adjust indicator to zero reading
5. Rotate camshaft one complete turn slowly while watching for highest meter reading

(NOTE: Check all inner shaft bearing journals in the same manner. If runout exceeds 0.003 inches dial indicator reading, replace the camshaft.)

FIGURE 86



F. Clean work area; clean and put away all tools and equipment

CLEANING, INSPECTING, AND RECONDITIONING
GASOLINE ENGINES
UNIT III

JOB SHEET #3 — CLEAN AND INSPECT HYDRAULIC LIFTERS

I. Equipment and materials

A. Basic hand-tool set

B. Eye protection

C. Cleaning solvent

D. Cleaning basket with separate compartments

E. SAE-10 motor oil

F. 1/8-inch drift pin

G. 1/16-inch drift pin

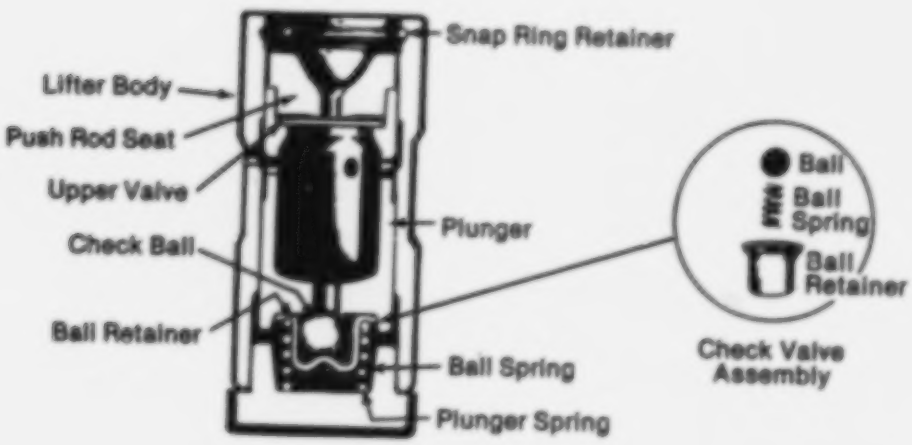
II. Procedure

A. Inspect lifter visually for wear or damage on base and for wear on push rod seat; replace if any damage or wear is evident

JOB SHEET #3

B. Disassemble hydraulic lifter (Figure 87)

FIGURE 87



1. Hold plunger down with a push rod
2. Remove push rod seat retainer ring
3. Remove push rod slowly
4. Remove push rod seat and upper valve
5. Remove plunger, ball check valve, and plunger spring

JOB SHEET #3

6. Remove ball check valve and spring from plunger by prying ball retainer with blade of a small screwdriver (Figure 88)

FIGURE 88

C. Clean and inspect lifter

1. Clean all parts thoroughly in cleaning solvent

(CAUTION: If more than one lifter is repaired at the same time, use caution not to interchange parts.)

2. Inspect lifter for worn or scuffed parts

(NOTE: If any one part is damaged, the entire lifter assembly should be replaced. If the outside of the lifter body is scuffed or worn, inspect the cylinder block lifter bore. If the bottom of the lifter is scuffed or worn, inspect the camshaft lobe. If the push rod seat is scuffed or worn, inspect the push rod.)

D. Assemble the hydraulic lifter

1. Place check ball on small hole on bottom of plunger

2. Insert check ball spring on seat in ball retainer

3. Place retainer over ball so that spring rests on ball

JOB SHEET #3

4. Use a small screwdriver blade to press retainer carefully into position in the plunger (Figure 89)

FIGURE 89

5. Place plunger spring over ball retainer

6. Slide lifter body over spring and plunger, being careful to line up oil feed holes in lifter body and plunger

7. Fill assembly with SAE-10 oil

8. Insert end of a 1/8-inch drift pin into plunger; press down firmly

   (NOTE: At this point, the holes in the lift body and plunger assembly will be aligned.)

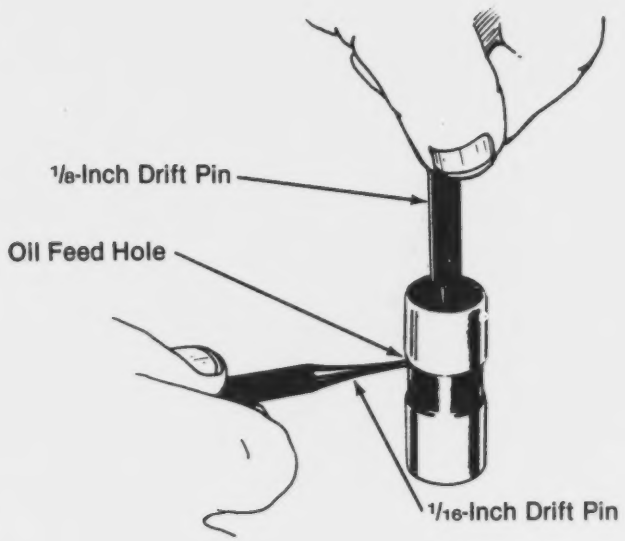
   (CAUTION: Do not attempt to force or pump the plunger. Severe damage to the lifter could result.)

JOB SHEET #3

9. Insert 1/16-inch drift pin through both oil holes to hold plunger against spring tension (Figure 90)

   (CAUTION: Use care not to damage internal parts of the lifter with either drift pin.)

FIGURE 90



10. Remove the 1/8-inch drift pin

11. Refill assembly with SAE-10 oil

12. Insert upper valve and push rod seat

13. Install push rod seat retainer

14. Push down on push rod seat and remove 1/16-inch drift pin from oil holes

    (NOTE: The lifter is now completely assembled, filled with oil, and ready for installation. Before installing any lifter, coat the bottom of the lifter with a good high-pressure lubricant such as Malykote or its equivalent.)

E. Clean work area; clean and put away all tools and equipment

CLEANING, INSPECTING, AND RECONDITIONING
GASOLINE ENGINES
UNIT III

JOB SHEET #4 — DISASSEMBLE, CLEAN, AND INSPECT
CYLINDER HEAD ASSEMBLY

I. Equipment and materials

- A. Valve spring compressor
- B. Drill motor
- C. Valve guide cleaner
- D. Carbon brush
- E. Dial indicator and adapter set
- F. Torque wrench
- G. Valve spring tension gauge
- H. Gasket scraper
- I. Carbon scraper
- J. Straightedge
- K. Feeler gauge assortment
- L. Cleaning solvent
- M. Bench-mounted buffing wheel
- N. Vat-type cleaner (optional)
- O. Valve board
- P. Basic hand-tool set
- Q. Eye protection
- R. Appropriate service manual

II. Procedure

- A. Disassemble cylinder head
  1. Remove rocker arms if not previously done

JOB SHEET #4

2. Loosen valve keepers by striking a downward blow on spring retainer

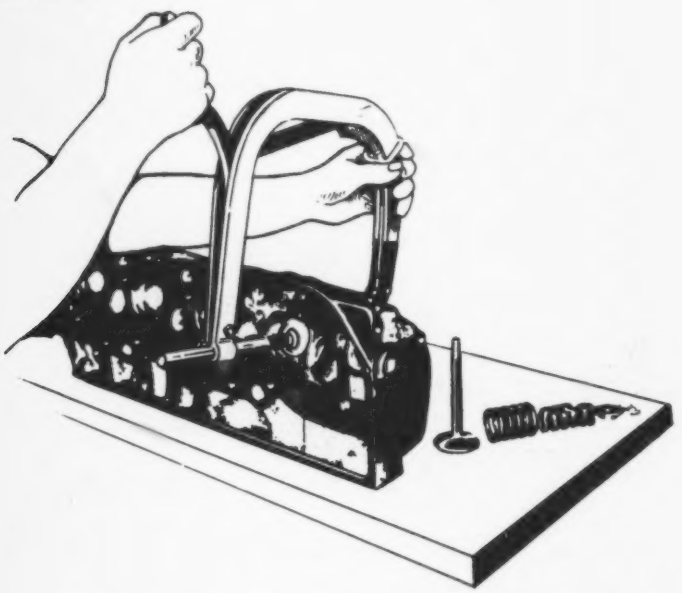
3. Compress valve springs and remove valve keepers (See Figure 91)

   (CAUTION: Point the valve spring so that it will hit the bench wall if the compressor should slip off.)

4. Release compressor slowly; remove spring assembly (See Figure 91)

5. Remove valve stem seal (Figure 91)

FIGURE 91



6. Remove any burrs or mushroomed conditions from valve stem before attempting to remove valve from cylinder head

JOB SHEET #4

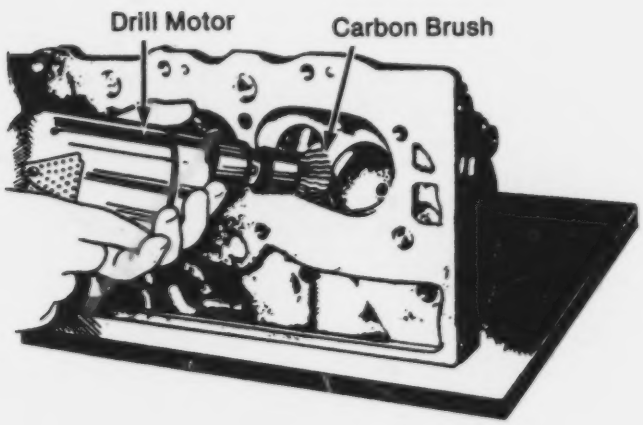
7. Remove valves from cylinder head and place on a rack in their proper sequence so that they can be reassembled in their original positions (Figure 92)

FIGURE 92

B. Clean cylinder head and valve parts

1. Clean all carbon from combustion chambers and head surfaces (Figure 93)

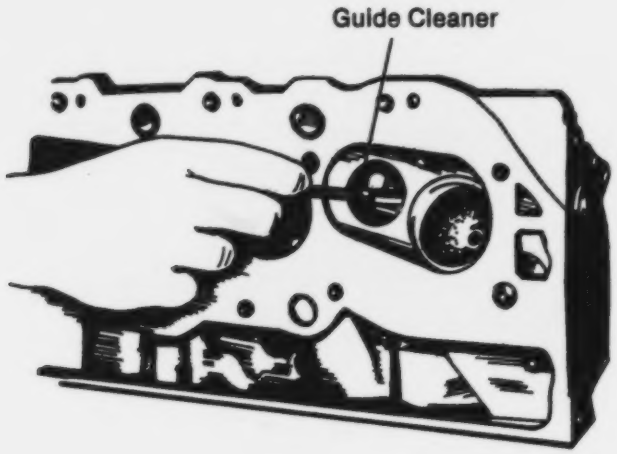
FIGURE 93



JOB SHEET #4

2. Clean valve guides, using guide cleaner (Figure 94)

FIGURE 94



a. Adjust cleaner blades to fit the guide snugly

b. Install cleaner in drill motor

c. Dip cleaner in solvent and insert in guide

d. Spin cleaner in guide while moving up and down the guide

3. Clean all carbon and sludge from push rods, rocker arms, and push rod guides

4. Clean valve stems and heads with buffing wheel

5. Clean carbon and gasket material from cylinder head gasket mating surfaces

C. Inspect cylinder head and valve assemblies

1. Inspect cylinder head for cracks in exhaust ports, combustion chambers, or water chamber

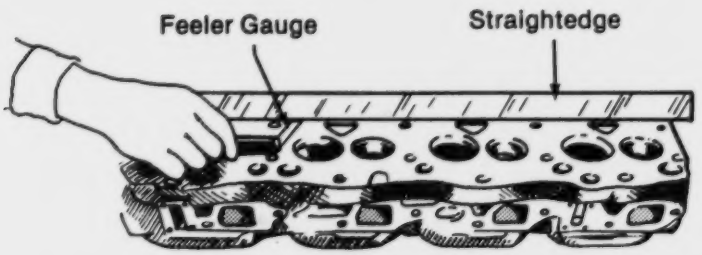
(NOTE: Suspected cracks may be tested with Magniflux or other suitable crack-detecting equipment.)

JOB SHEET #4

2. Check cylinder head gasket mating surface for warpage (Figure 95)

   (NOTE: If an 0.004-inch feeler gauge will go between the head surface and straightedge at any position, the cylinder head will require resurfacing.)

FIGURE 95



3. Check all bolt hole threads

4. Inspect valves for burned heads, cracked faces, or damaged stems

5. Measure valve stem clearance (See Figure 96)

   a. Clamp a dial indicator on side of cylinder head

   b. Locate indicator so that movement of valve stem from side to side will cause a direct movement of the indicator stem

      (NOTE: The indicator stem must contact the valve stem just above the valve guide.)

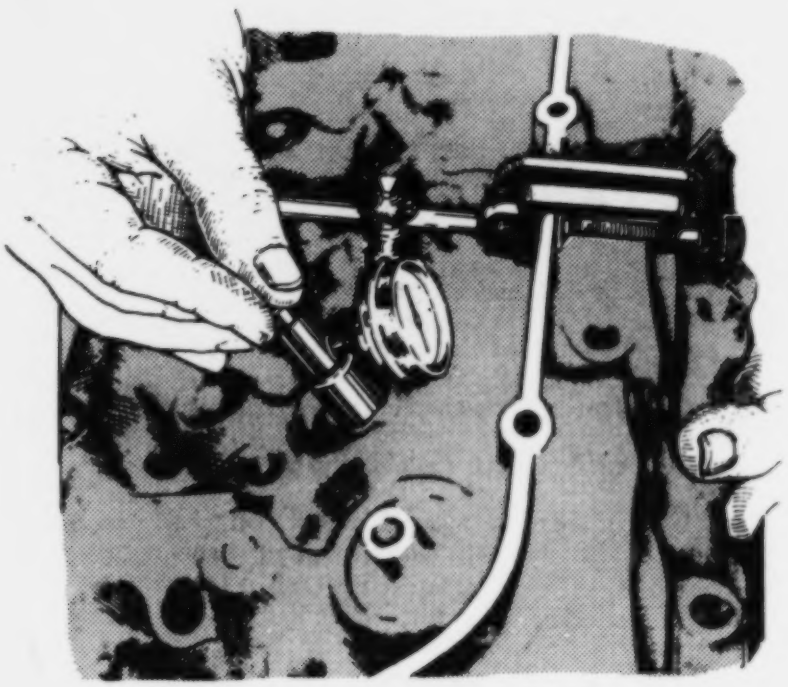
   c. Lower valve head about 1/16 inch off valve seat

      (NOTE: A new valve should be used for accurately determining valve guide wear.)

d. Move valve stem from side to side, using light pressure, to obtain a clearance reading

(NOTE: Refer to service manual specifications to determine the proper clearance and the repairs that may be necessary.)

FIGURE 96



6. Check valve spring tension

a. Compare valve spring free-standing height

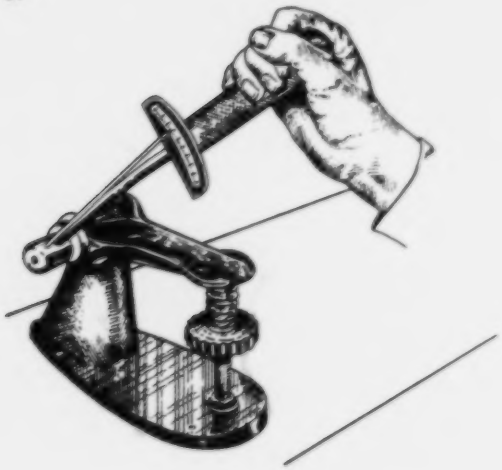
(NOTE: Springs should be within 1/8-inch of each other without leaning or other distortions.)

JOB SHEET #4

b. Check valve spring with spring tester (Figure 97)

(NOTE: Spring should be compressed to the specified height and checked against the service manual specification chart for torque. Springs should be replaced if not within 10 foot-pounds of the specified load.)

FIGURE 97



7. Inspect push rod condition

a. Inspect push rods for straightness

(NOTE: Inspection can be accomplished by rolling the push rod on a flat surface and watching for a wobbling condition.)

b. Inspect push rod ends for wear, chipping, or other damage

8. Inspect rocker arms

a. Inspect rocker arms for wear at push rod seat, valve stem reaction area, and shaft or pivot area

b. Inspect rocker arm shaft, if rocker arm is so equipped, for wear, scoring, or cracks

c. Inspect rocker arm studs, if rocker arm is so equipped, for wear, looseness in cylinder head, or damaged threads

d. Inspect rocker arm stands, studs, and pivot balls for wear or damage

D. Clean work area; clean and put away all tools and materials

CLEANING, INSPECTING, AND RECONDITIONING
GASOLINE ENGINES
UNIT III

JOB SHEET #5 — RECONDITION CYLINDER HEAD

I. Equipment and materials

A. Basic hand tool set

B. Torque wrench

C. Rocker arm stud puller

D. Rocker arm stud driver

E. Valve seat grinding equipment

F. Valve grinding equipment

G. Valve spring compressor

H. 6-inch steel scale with 1/32-inch markings

I. Lead pencil

J. Assortment of guide reamers

K. Valve seat indicator

L. Eye protection

M. Appropriate service manual

II. Procedure

A. Replace rocker arm studs

1. Replace threaded-type stud

a. Unscrew old rocker arm stud

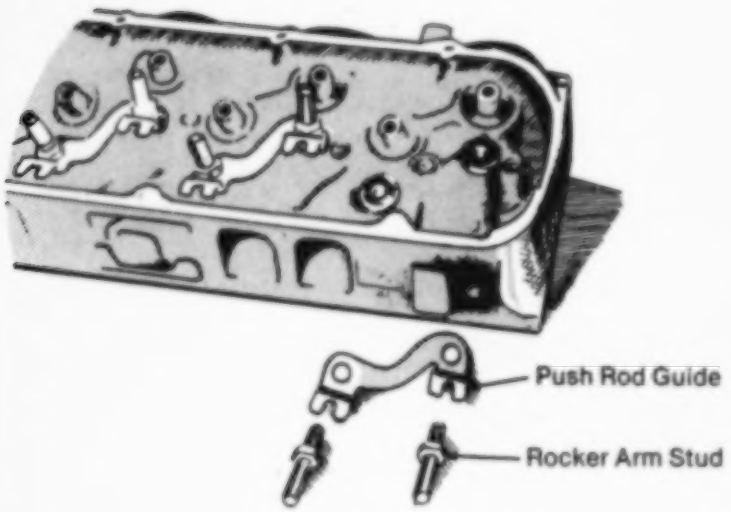
(NOTE: Some rocker studs retain the push rod guides that must be replaced in the same position.)

b. Apply a coat of sealer to stud threads on cylinder head end

JOB SHEET #5

c. Install stud and torque to specifications (Figure 98)

FIGURE 98

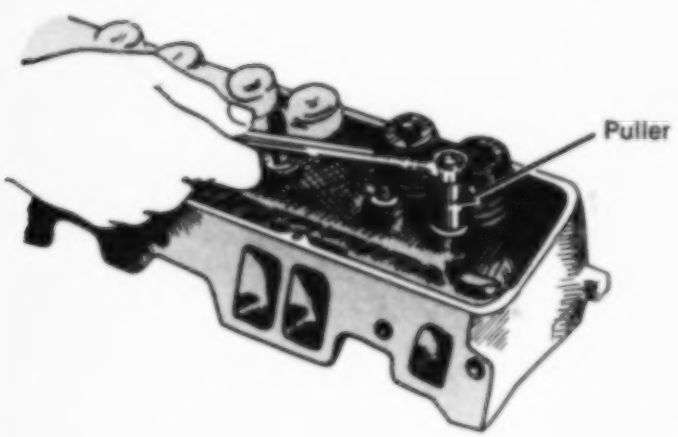


2. Replace press-in stud

a. Remove old stud with stud puller (Figure 99)

(NOTE: Lubricate threads and puller surface to aid in pulling the stud. The puller could be a short piece of pipe or a stack of washers.)

FIGURE 99



JOB SHEET #5

b. Ream stud hole to fit oversized stud (Figure 100)

(CAUTION: Do not attempt to install an oversized stud without reaming stud hole.)

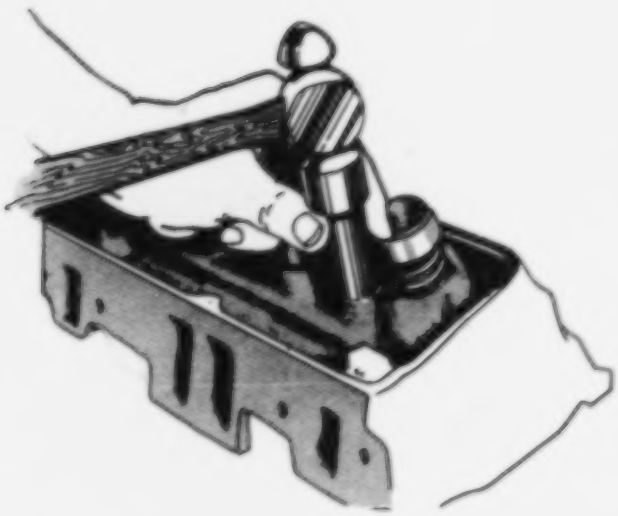
FIGURE 100

c. Coat press-fit area of stud with hypoid-axle lubricant

(CAUTION: Avoid trapping any lubricant in the stud hole. This may prevent stud from reaching its proper depth.)

d. Install new stud with special driver gauge until stud bottoms on head (Figure 101)

FIGURE 101



B. Repair worn valve guides

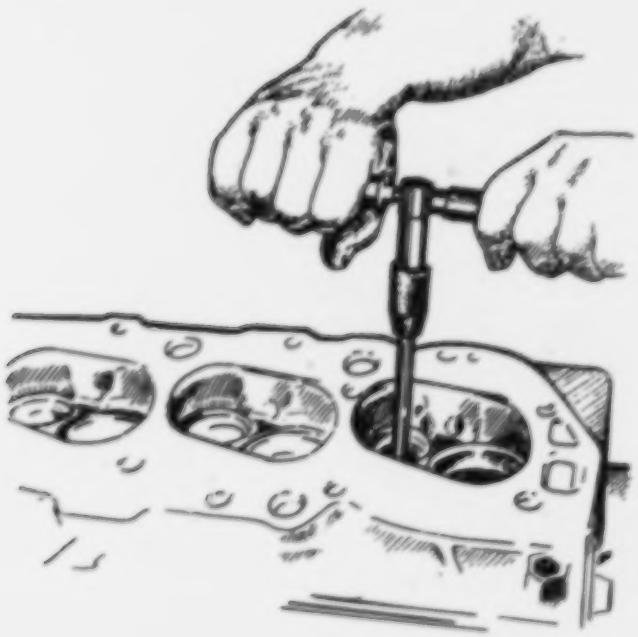
(NOTE: Excessively worn valve guides may be repaired by reaming the guide to an oversize and using oversized valve stems; or by machining the cylinder head and installing replaceable guides. Both methods are recommended. The technician should consider the cost when making recommendations. An alternate but less effective method is to knurl the existing guide.)

1. Install reamer handle on proper-sized reamer for valve stem to be used

JOB SHEET #5

2. Ream guides, using caution to start reamer straight (Figure 102)

FIGURE 102



C. Recondition valve seats

(NOTE: Several different types of equipment are available for grinding valve seats. The recommendation of the manufacturer should be carefully followed to obtain proper results. Regardless of what type equipment is used, however, it is essential that the valve guide bore is clean of carbon or dirt to ensure proper centering of the pilot in the guide.)

1. Reface stones to obtain a smooth, true surface
2. Install pilot in valve guide
3. Place roughing stone or forming stone over pilot; clean valve seat

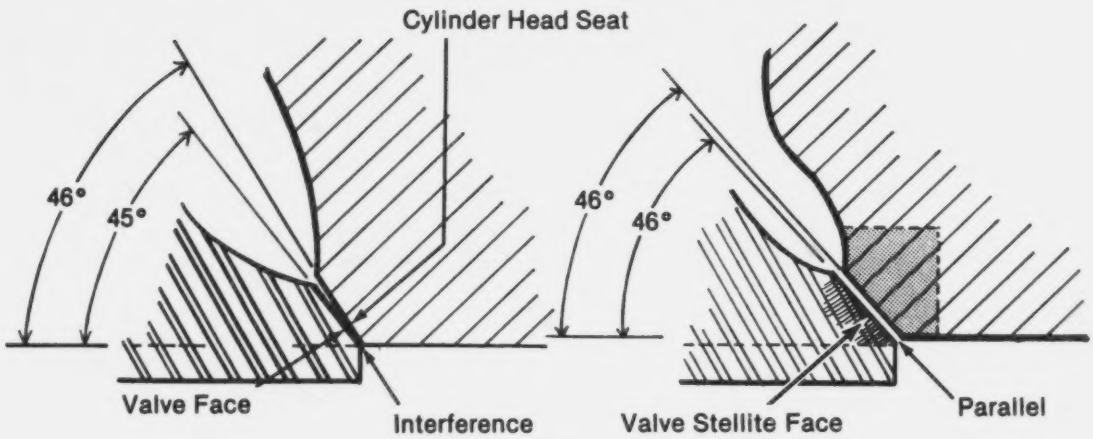
   (NOTE: Use a stone dressed to the specified angle.)
4. Remove roughing or forming stone from pilot
5. Place finishing stone, and grind to remove just enough metal to provide a smooth finish (See Figure 103)

JOB SHEET #5

6. Narrow valve seat to specified width

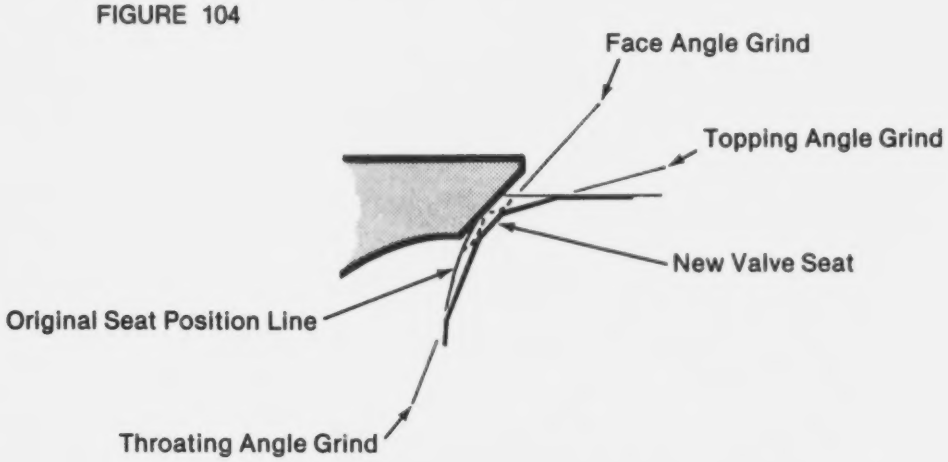
(NOTE: This operation is done by grinding the port side with a 30-degree stone to lower seat and a 60-degree stone to raise seat. Use 30-degree and 60-degree stone for a 45- or 46-degree angle, and 15-degree and 60-degree stone for 30- or 29-degree face angle. See Figure 103.)

FIGURE 103



7. Adjust valve seat position so that seat strikes valve face slightly below center of face (Figure 104)

FIGURE 104



JOB SHEET #5

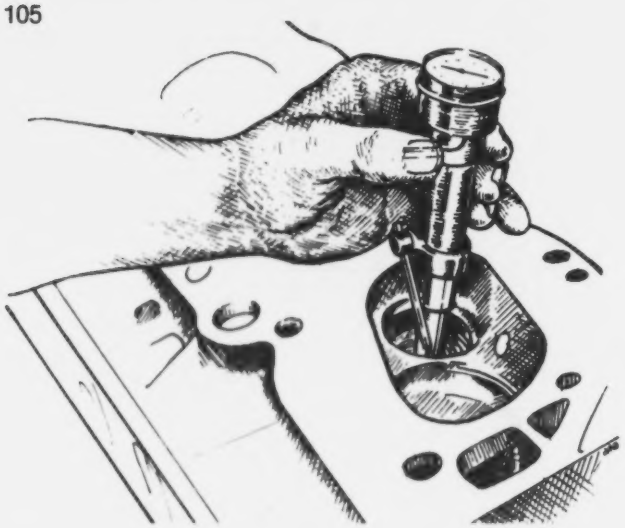
8. Remove pilot from cylinder head

9. Clean cylinder head carefully to remove all chips and grindings accumulated during grinding operation

10. Measure valve seat roundness (Figure 105)

    (NOTE: Valve seat must be rounded to within 0.002 inch of total indicator reading.)

FIGURE 105



D. Recondition valves

(NOTE: Valves that are pitted can be refaced to the proper angle, ensuring correct relation between the head and stem. Replace valves if the stems show excessive wear, if the heads are warped, or if the margins have been ground too thin.)

1. Dress valve refacing machine's grinding wheel to make sure that it is smooth and true

2. Set chuck at angle specified for valve

3. Clamp valve stem in chuck

4. Start machine; move valve head in line with grinder wheel

5. Observe valve head rotation for excessive out-of-round

6. Turn on grinder coolant

JOB SHEET #5

7. Adjust coolant nozzle so that valve head will have coolant running on it when grinding

8. Turn feed screw until valve head just contacts wheel

9. Move valve head back and forth across wheel while regulating feed to maintain a light valve contact

   (CAUTION: Do not let the valve face move off the grinding wheel while they are in contact. This will rough up the valve face and groove the wheel.)

10. Continue grinding until valve face is true and smooth

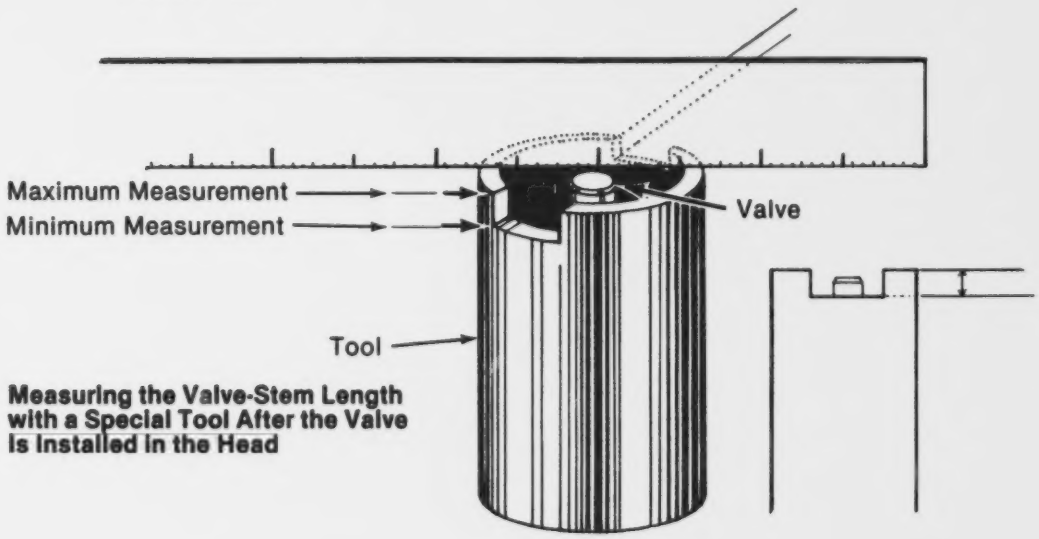
    (NOTE: If grinding makes the valve margin too thick [less than 1/16 inch], the valve must be replaced.)

11. Remove valve from chuck

12. Place valve in V-block to resurface end of stem

    (NOTE: Before grinding valves on an engine with nonadjustable rocker arms, place the valve in the cylinder head and measure the valve stem height so that the amount of resurfacing will maintain correct stem height. See Figure 106.)

FIGURE 106



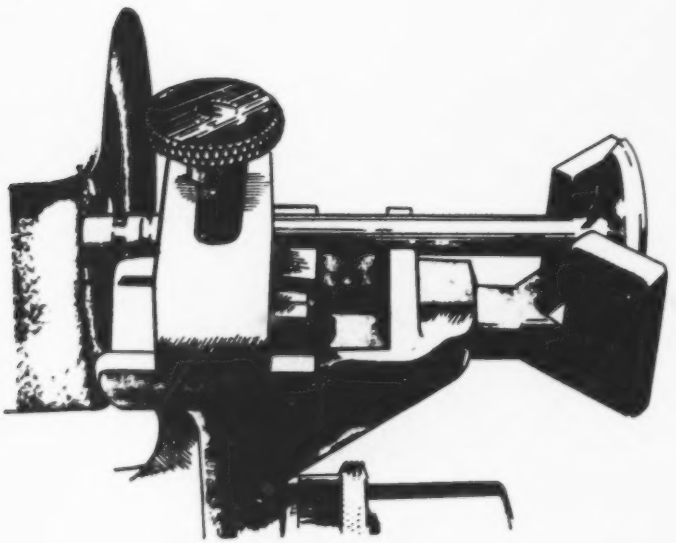
Measuring the Valve-Stem Length with a Special Tool After the Valve Is Installed in the Head

JOB SHEET #5

13. Feed valve squarely against grinding wheel; remove only enough metal to remove pits from stem end (Figure 107)

(CAUTION: Only the extreme end of the valve stem is hardened to resist wear. Do not grind stems excessively. Some manufacturers recommend that valve stems not be resurfaced for any reason. If damaged, they must be replaced.)

FIGURE 107



14. Chamfer valve stem

15. Clean cylinder head and valves of all grinding particles

16. Make pencil marks about 1/4-inch apart across valve face

17. Place valve in cylinder head and give it about half a turn in each direction while exerting firm pressure on valve head

18. Remove valve and check face carefully

(NOTE: If all pencil marks have not been removed at the point of contact with the seat, it will be necessary to repeat the refacing operation and then recheck for proper seating.)

19. Grind and check remaining valves in same manner

E. Reassemble cylinder head

1. Lubricate valve stem

JOB SHEET #5

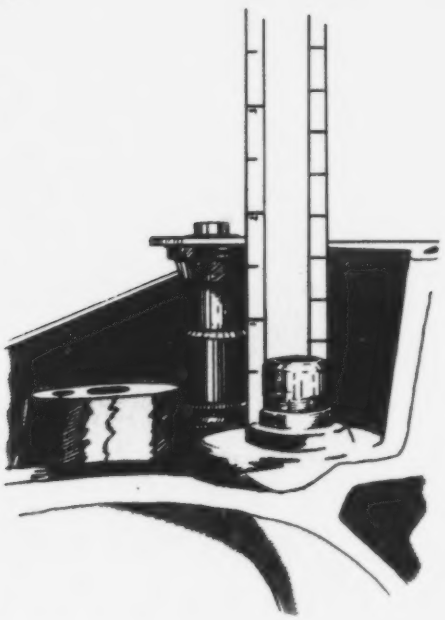
2. Insert a valve in the proper port

3. Check installed height of valve springs by measuring from top of shim or spring seat to top of spring retainer (Figure 108)

   (NOTE: Adjust the shim thickness to correct the installed height of the spring to specifications.)

   (CAUTION: At no time should the spring be shimmed to give an installed height under the minimum specified.)

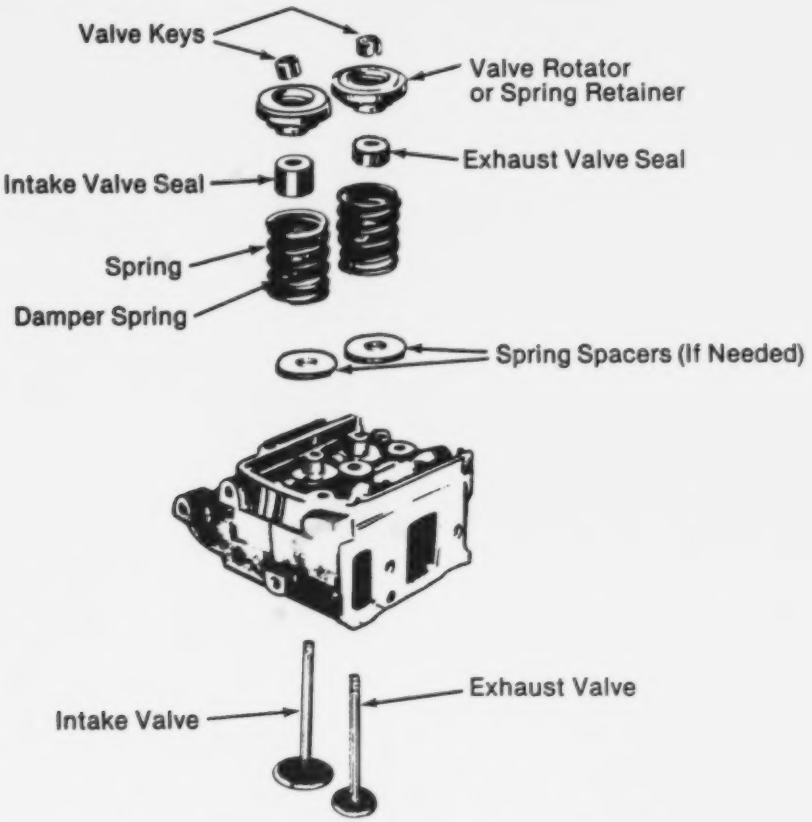
FIGURE 108



JOB SHEET #5

4. Assemble valve parts in the proper order (Figure 109)

FIGURE 109



5. Compress spring with spring compressor

6. Install O-ring seal, if used, in second groove of valve stem

   (NOTE: Be sure that seal is even and flat in the groove.)

7. Install valve keepers and release compressor tool, making sure that keepers seat properly in upper grooves of stem

8. Tap valve stem end to seat valve spring keepers

F. Clean work area; clean and put away all tools and equipment

CLEANING, INSPECTING, AND RECONDITIONING
GASOLINE ENGINES
UNIT III

JOB SHEET #6 — CHECK MAIN BEARING BORE ALIGNMENT

I. Equipment and materials

A. Straight edge

(NOTE: The straight edge should be as long as the cylinder block.)

B. Feeler gauge set

C. Telescoping gauge

D. Micrometer

E. Clean shop towel

F. Engine oil

G. Appropriate service manual

II. Procedure

(NOTE: There are two methods of checking the main bearing bores for warpage. One method is to install a special, properly ground arbor, 0.001 inch smaller than the bearing bore, in place of the crankshaft. If the arbor will turn with a 12-inch crank, the block is not warped. The other method, which does not require a special arbor, will be described in this job sheet.)

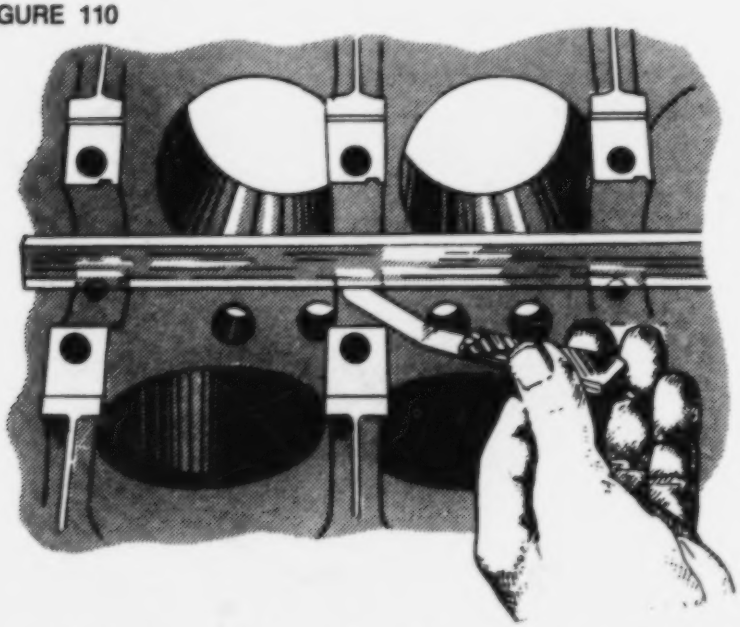
A. Remove crankshaft, upper main bearing halves, and rear main bearing seal if not already accomplished

B. Clean main bearing bore and cap bosses thoroughly; air dry

JOB SHEET #6

C. Place straightedge at bottom of main bearing (Figure 110)

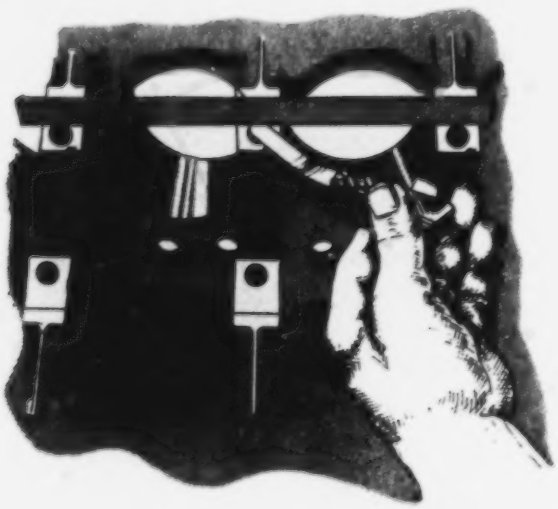
FIGURE 110



D. Check clearance between each bearing bore surface and straightedge

E. Place straightedge on main bearing cap bosses (Figure 111)

FIGURE 111



JOB SHEET #6

F. Check clearance between straightedge and bosses

(NOTE: Clearance between the surface and straightedge should not exceed one-half the allowable bearing clearance. If the clearance is greater than one-half the allowable clearance, the block will have to be remachined or discarded.)

G. Check bearing bore for out-of-round

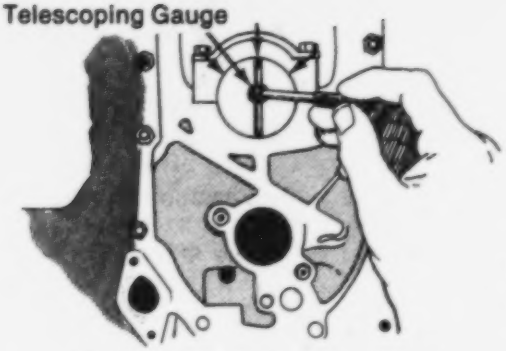
1. Install main bearing cup, and torque to specifications

(NOTE: Leave the bearing inserts out when checking bore out-of-round.)

2. Measure the bearing bore at three locations (Figure 112)

FIGURE 112

Telescoping Gauge



Measure bore in three locations.

Measure telescoping gauge.

3. Compare the three measurements to obtain bore out-of-round

(NOTE: Check service manual for allowable bore out-of-round. If out-of-round exceeds allowable limits, the block bore will have to be line bored by a machinist to correct the condition.)

H. Clean work area; clean and put away all tools and equipment

CLEANING, INSPECTING, AND RECONDITIONING
GASOLINE ENGINES
UNIT III

JOB SHEET #7 — MEASURE AND INSPECT A CRANKSHAFT

I. Equipment and materials

A. Micrometer, 0 to 3-inch range

B. Dial indicator

C. Feeler gauge

D. 2 V-blocks

E. Clean shop towel

F. 10-W engine oil

G. Appropriate service manual

II. Procedure

A. Inspect crankshaft for worn, burned, scored, pitted, rough, flaked, cracked, or otherwise damaged journals

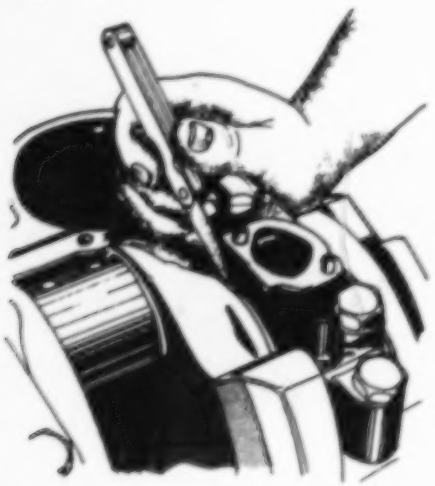
B. Inspect for damage to crankshaft gear and vibration damper mounting areas and keyways

C. Inspect shaft thrust surface for wear or damage

JOB SHEET #7

D. Measure with a feeler gauge the clearance between thrust bearing and shaft thrust surface (Figure 113)

FIGURE 113



E. Inspect flywheel flange for damage, and check bolt holes for thread condition

F. Inspect transmission pilot bearing area in flywheel flange for wear or damage

G. Measure a main bearing journal for out-of-round (Figure 114)

1. Measure main bearing journal at midposition between oil hole and fillet; record measurement

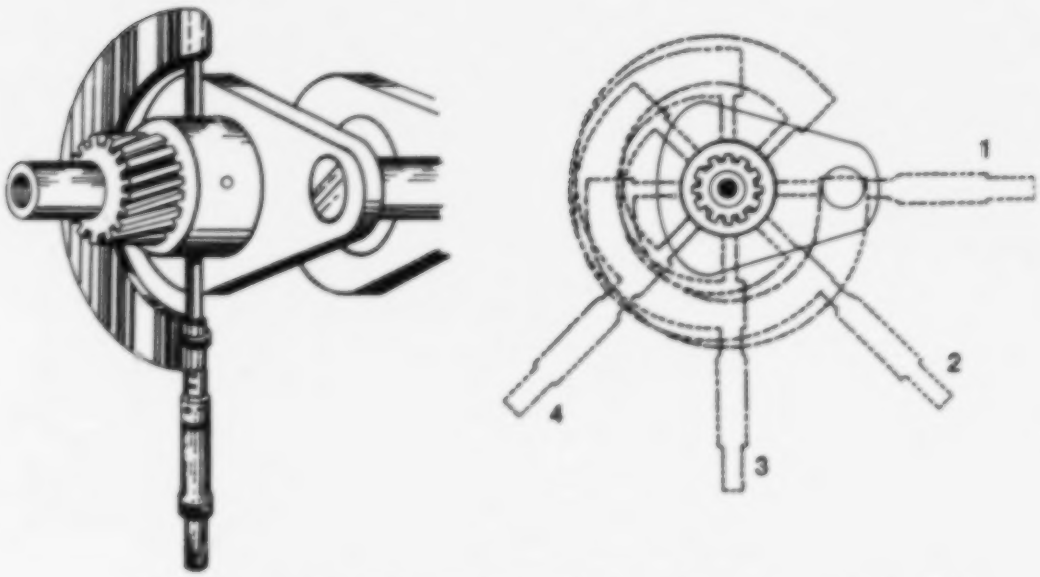
2. Measure journal at four positions at 45-degree intervals from midposition measurement; record measurements

(NOTE: The shaft readings should not vary more than 0.001 inch.)

JOB SHEET #7

3. Compare the four measurements for out-of-round

FIGURE 114



H. Measure a main bearing journal for taper or unevenness (Figure 115)

1. Measure main bearing journal just off fillet; record measurement

_____

2. Measure main bearing journal in center, but not at oil hole; record measurement

_____

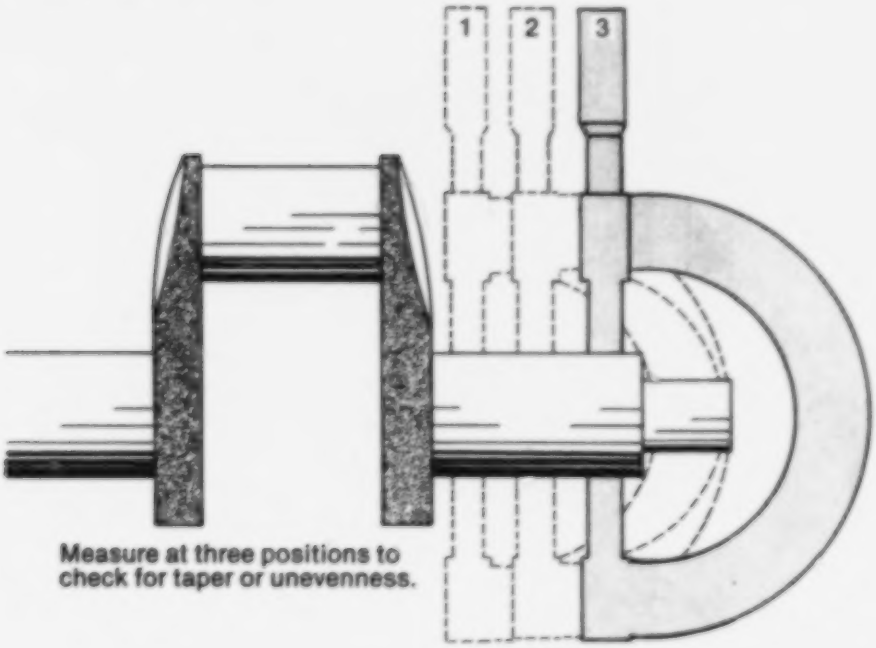
3. Measure main bearing journal just off other fillet; record measurement

_____

4. Compare the three measurements

   (NOTE: The variation should not exceed 0.0005 inch. Compare these measurements to manufacturer's specifications to determine the amount of wear on the journal.)

FIGURE 115



Measure at three positions to check for taper or unevenness.

I. Measure each remaining bearing journal in same manner as in steps A and B; record taper, out-of-round, and wear for each

J. Check crankshaft for a bent condition (Figure 116)

   1. Place crankshaft on V-blocks so that blocks contact ends of main bearing journals

      (NOTE: If V-blocks are not available, the main bearing caps may be used.)

   2. Place a few drops of 10-W oil on each end of main journal

   3. Position dial indicator so that contact will be against centermost main bearing journal

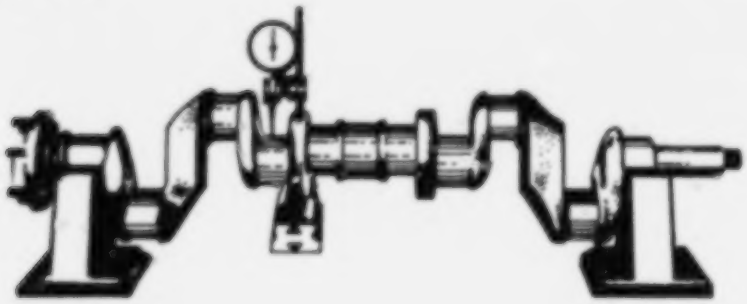
   4. Set the indicator hand to zero

JOB SHEET #7

5. Rotate crankshaft slowly while observing maximum indicator reading

(NOTE: If shaft is tapered or out-of-round more than 0.0005-inch or 0.0001-inch respectively, the crankshaft will require remachining or replacement. If any cracks are found, the shaft must be replaced. Other defects should be evaluated with the assistance of the instructor.)

FIGURE 116



K. Clean work area; clean and put away all tools and equipment

CLEANING, INSPECTING, AND RECONDITIONING
GASOLINE ENGINES
UNIT III

JOB SHEET #8 — FIT A CRANKSHAFT BEARING WITH PLASTIGAUGE

I. Equipment and materials

- A. Basic hand-tool set
- B. Torque wrench
- C. Plastigauge
- D. Clean shop towel
- E. Appropriate service manual

II. Procedure

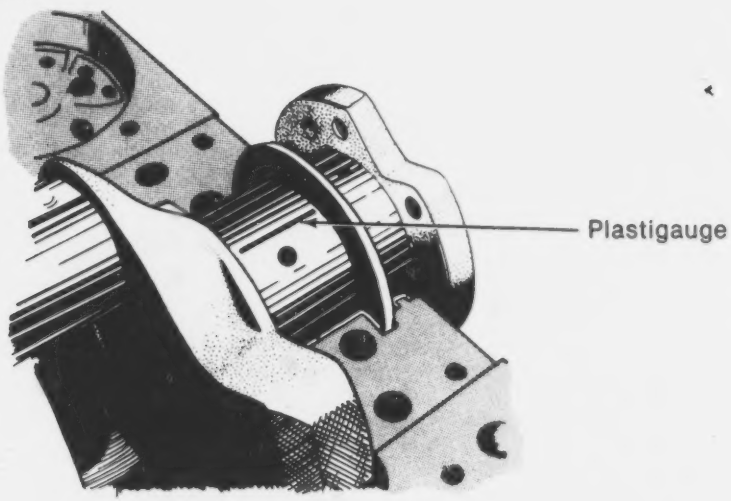
- A. Check main bearing clearance with engine out of vehicle

  (NOTE: The engine block should be turned so that the crankcase is facing up. This will allow the weight of the crankshaft to rest on the upper bearing halves, leaving the clearance between the shaft and the bearing cap.)

  1. Torque all main bearing cap bolts to specified torque
  2. Remove bearing cap from bearing journal to be checked
  3. Clean oil from bearing and cap
  4. Clean oil from exposed portion of main bearing journal

5. Place a piece of Plastigauge the full width of the bearing journal and parallel to shaft (Figure 117)

FIGURE 117



6. Install bearing cap, and evenly torque retaining bolts to service manual specifications

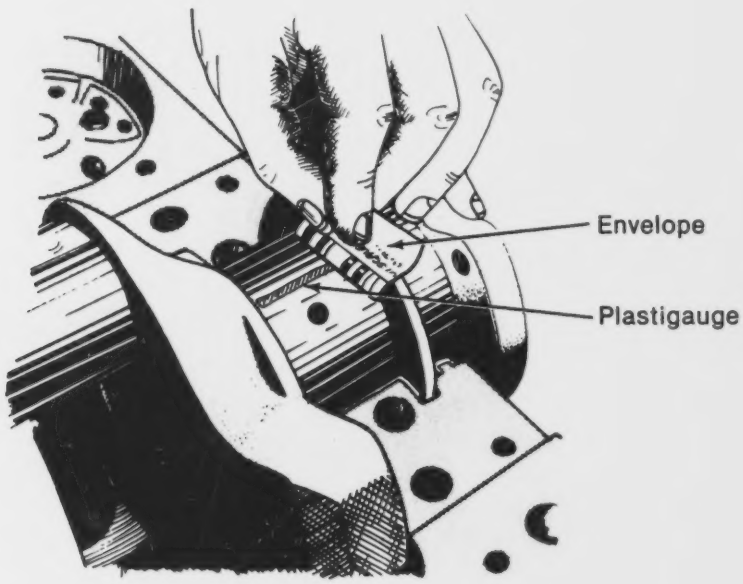
(CAUTION: Do not rotate the crankshaft while the Plastigauge is between the bearing insert or journal.)

JOB SHEET #8

7. With the graduations on the Plastigauge envelope, measure compressed width at widest point (Figure 118)

(NOTE: The graduated scale is correlated in thousandths of an inch.)

FIGURE 118



(NOTE: If a bearing is being fitted to an out-of-round journal [maximum 0.001 inch] be sure to fit to the maximum diameter of the journal. If flattened Plastigauge tapers toward the middle or ends, the difference in clearance indicates taper, low spot, ot other irregularity of the bearing or journal. Be sure to measure the journal with a micrometer if the Plastigauge varies more than 0.001 inch.)

8. Check all rod and main bearings in this manner

B. Set up crankshaft to gauge bearing clearance when engine is in vehicle

(NOTE: Except for the set-up procedures, the procedure for measuring bearing clearance is the same whether the engine is in or out of the vehicle.)

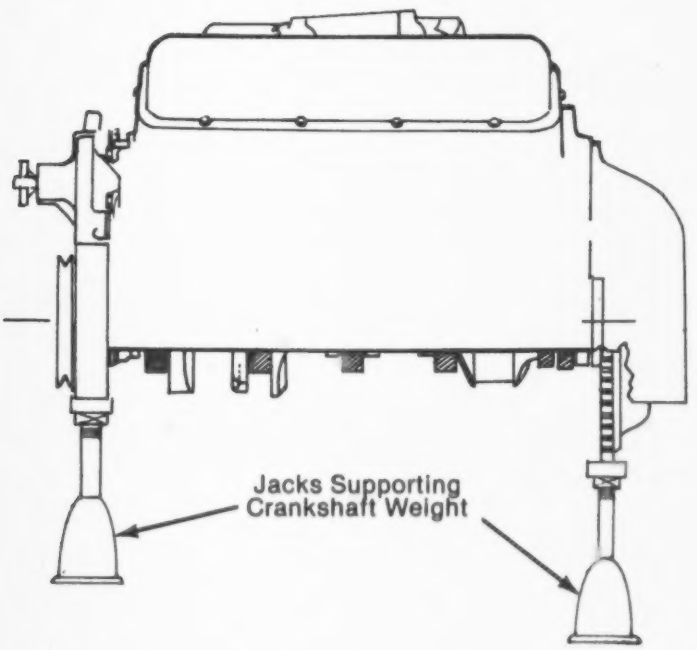
1. Remove oil pan and oil pump

2. Support crankshaft front and rear (Figure 119)

   (NOTE: A jack on the flywheel and one on the vibration damper will allow all bearings to be checked without moving jacks.)

   (CAUTION: The shaft must be held solidly in the upper bearing half in order to obtain an accurate clearance measurement.)

FIGURE 119



3. Gauge main bearing clearance in same manner as it was gauged with engine out of the vehicle in step A

C. Clean work area; clean and put away all tools and equipment

CLEANING, INSPECTING, AND RECONDITIONING
GASOLINE ENGINES
UNIT III

JOB SHEET #9 — INSTALL A REAR MAIN BEARING SEAL

I. Equipment and materials

A. Basic hand-tool set

B. Cylinder block

C. Rope-type seal

D. Lip-type seal

E. Seal driver or appropriate substitute

F. Eye protection

G. Appropriate service manual

II. Procedure

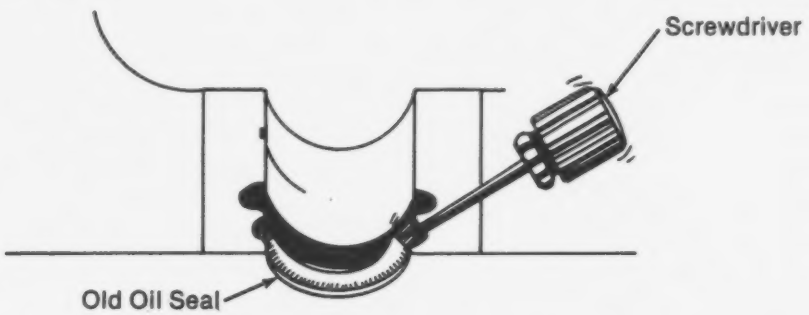
(NOTE: This job sheet will describe procedures for installing the two most used types of rear main bearing seals. It is very important that the seals fit properly to avoid seal damage or oil leaks.)

A. Install a rope-type rear main bearing seal

1. Remove crankshaft if not already accomplished

2. Remove old seal from block and bearing cap by prying it out with a small screwdriver (Figure 120)

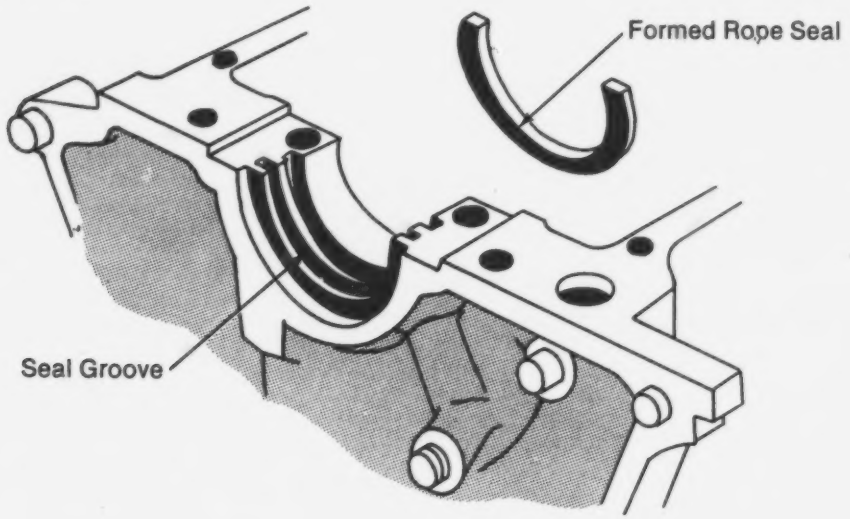
FIGURE 120



3. Clean seal groove in block and bearing cap

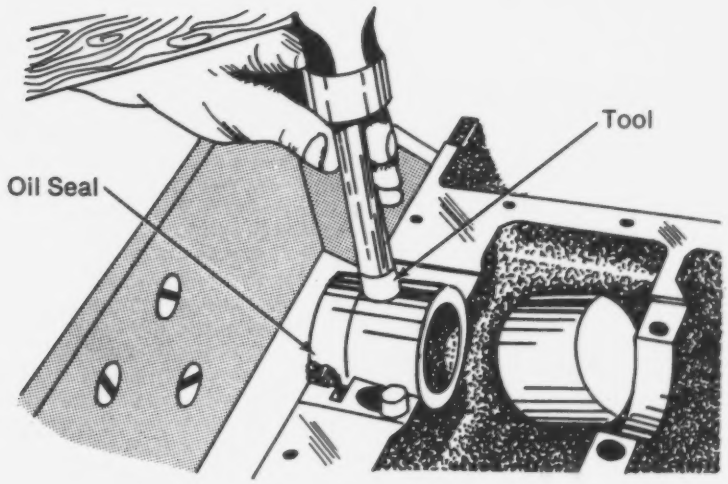
4. Form new seal half into semicircle approximately the diameter of the seal groove (Figure 121)

FIGURE 121



5. Place seal in groove so that both ends remain above ends of groove (Figure 122)

FIGURE 122



JOB SHEET #9

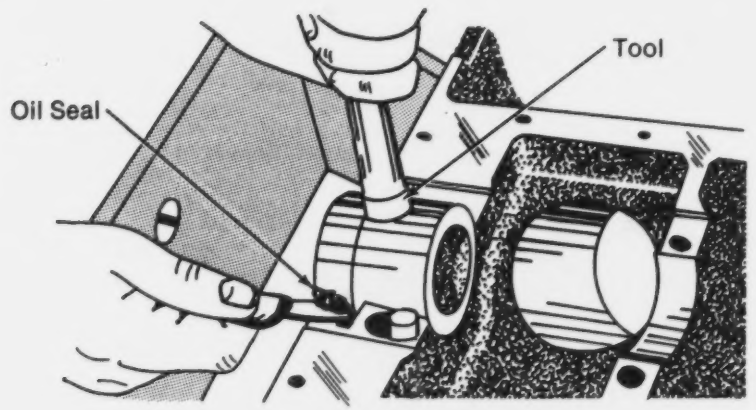
6. Use driver or suitable replacement to seat seal in groove

   (NOTE: If driver is not available, a round object just smaller than the crankshaft journal may be used to tap the seal gently into place.)

   (CAUTION: Do not overcompress seal.)

7. Trim ends of seal flush with block (Figure 123)

FIGURE 123



8. Install bearings in cylinder block

   (NOTE: Be sure that the oil hole in the bearing aligns with the oil hole in the block and that the bearing positioning tang is in its groove.)

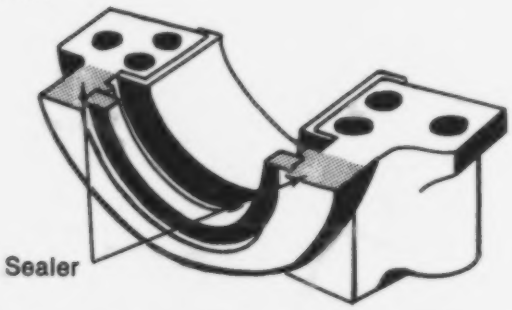
9. Apply a light film of oil on seal edge contacting crankshaft

10. Install crankshaft

11. Install rope seal in bearing cap in same manner as the block half was installed in steps 1 through 8

12. Apply a light coat of nonhardening sealer to darkened area of main bearing cap (Figure 124)

FIGURE 124



13. Install bearing insert in main bearing caps; lubricate

14. Install main bearing cap; torque bolts

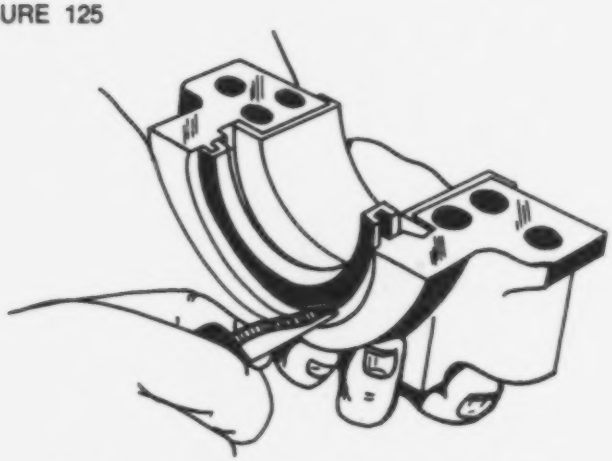
B. Install a split-lip rear main bearing seal

1. Remove crankshaft if not already accomplished

2. Remove old seal from block and bearing cap (Figure 125)

(NOTE: This seal can be removed and installed with the crankshaft in place if this is the only reason for removing the shaft.)

FIGURE 125



3. Clean seal groove or ridge thoroughly

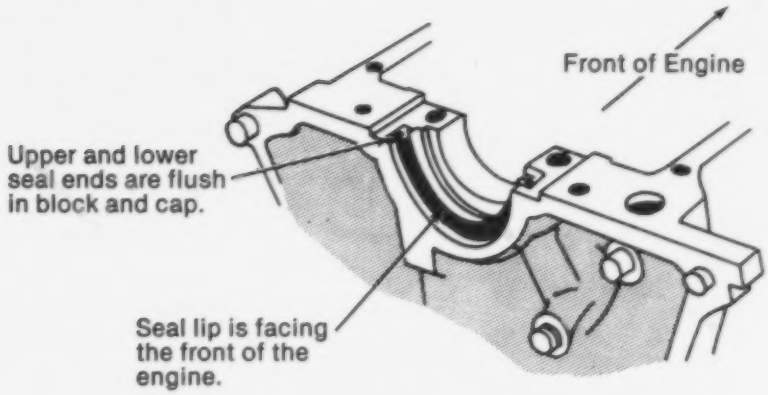
4. Dip seal in oil

JOB SHEET #9

5. Install seal in block and main bearing cap so that ends are flush with edges (Figure 126)

   (NOTE: The seal lip should be facing the front of the engine.)

FIGURE 126

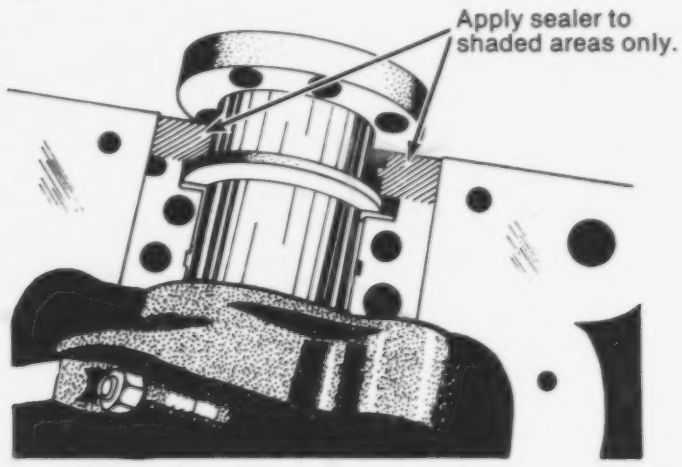


6. Install crankshaft

7. Apply a thin coat of sealer to main bearing cap seat in areas shaded in Figure 127

   (NOTE: No sealer should touch the seal lip.)

FIGURE 127



8. Install bearing cap; torque bolts to service manual specifications

C. Clean work area; clean and put away all tools and equipment

CLEANING, INSPECTING, AND RECONDITIONING
GASOLINE ENGINES
UNIT III

JOB SHEET #10 — DISASSEMBLE, CLEAN, AND INSPECT AN OIL PUMP

I. Equipment and materials

- A. Basic hand-tool set
- B. Micrometer, 0 to 1-inch
- C. Straightedge
- D. Feeler gauge set
- E. Drill motor
- F. 1/8-inch drill
- G. Soft-jawed vise
- H. Eye protection
- I. Appropriate service manual

II. Procedure to disassemble, clean, and inspect a rotor-type pump

- A. Remove pressure regulator valve

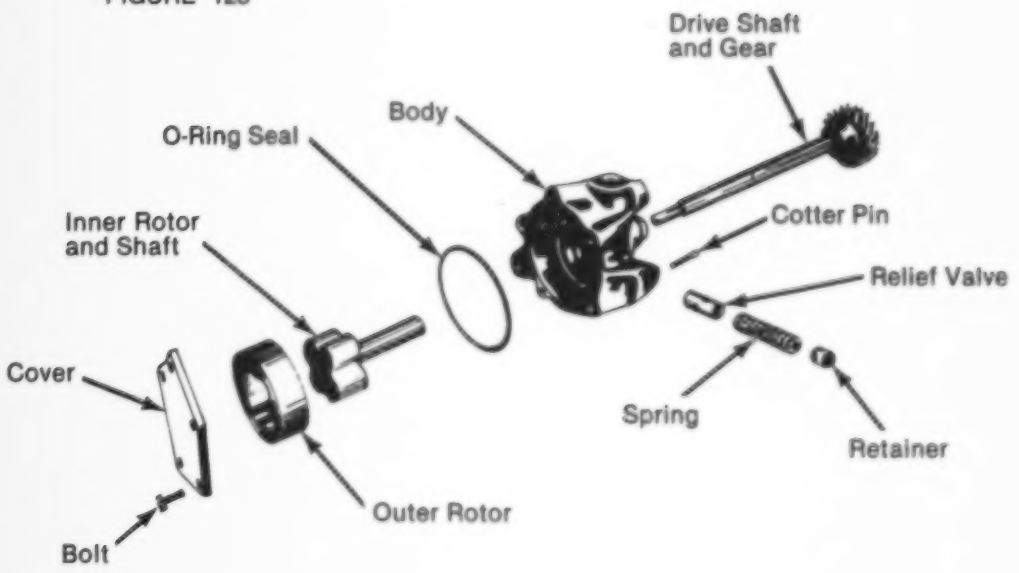
  (NOTE: Refer to Figure 128 on the following page.)

  1. Remove cotter pin
  2. Drill a 1/8-inch hole into regulator valve retainer cap
  3. Thread a sheet-metal screw into cap
  4. Remove cap with screw
- B. Remove oil pump cover bolts and lock washers
- C. Remove oil pump cover
- D. Discard oil seal ring
- E. Remove pump rotor and shaft

JOB SHEET #10

F. Remove outer rotor

FIGURE 128



G. Clean all parts thoroughly in clean solvent

H. Inspect pump cover mating surfaces for smoothness

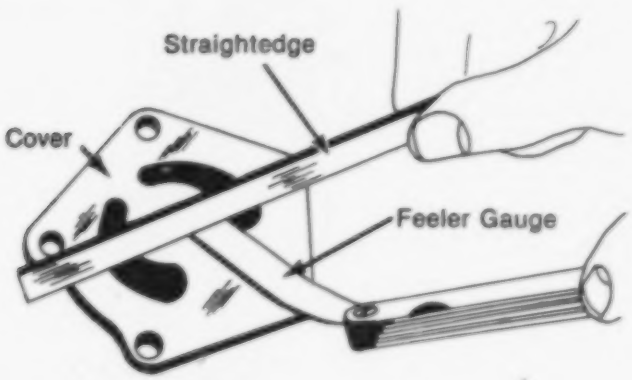
(NOTE: Replace the oil pump if the cover is scratched or grooved.)

JOB SHEET #10

I. Lay a straightedge across pump cover surface (Figure 129)

(NOTE: If an 0.0015-inch feeler gauge can be inserted between cover and straightedge, replace pump assembly.)

FIGURE 129

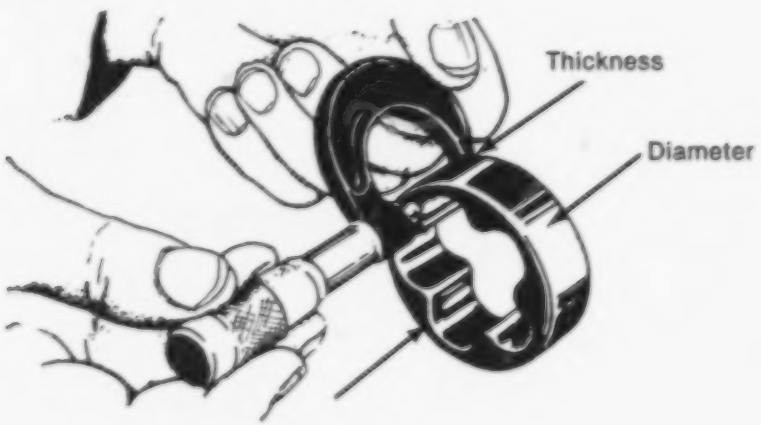


Checking Oil Pump Cover Flatness

J. Measure thickness and diameter of outer rotor (Figure 130)

(NOTE: If rotor thickness or diameter is below service manual specifications, replace the pump.)

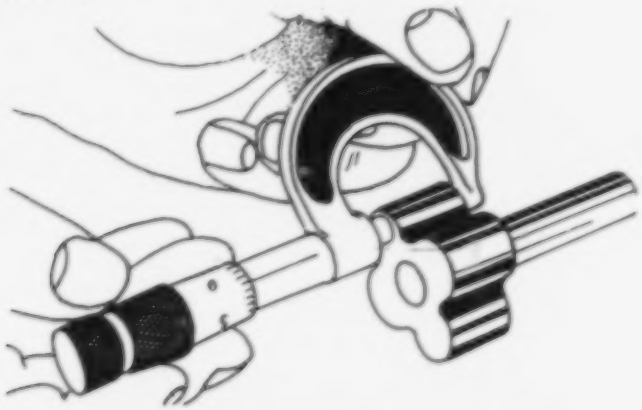
FIGURE 130



JOB SHEET #10

K. Measure thickness of inner rotor (Figure 131)

FIGURE 131



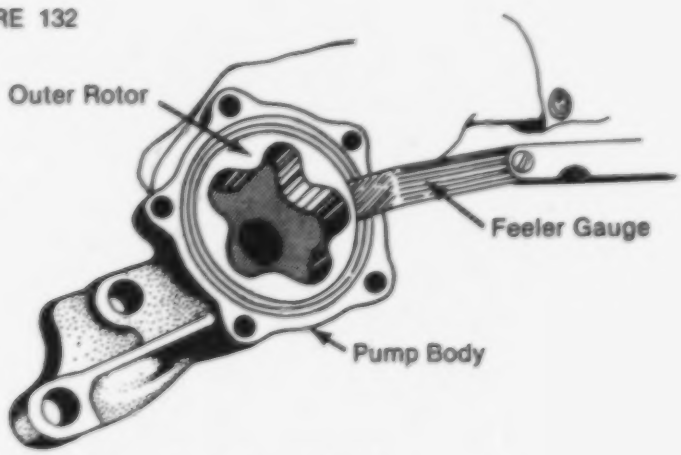
L. Inspect pump body visually for wear or scoring

M. Place outer rotor into pump body

N. Press rotor to one side with fingers, and measure clearance between rotor and pump body (Figure 132)

(NOTE: If measurement exceeds service manual specifications, replace the pump.)

FIGURE 132



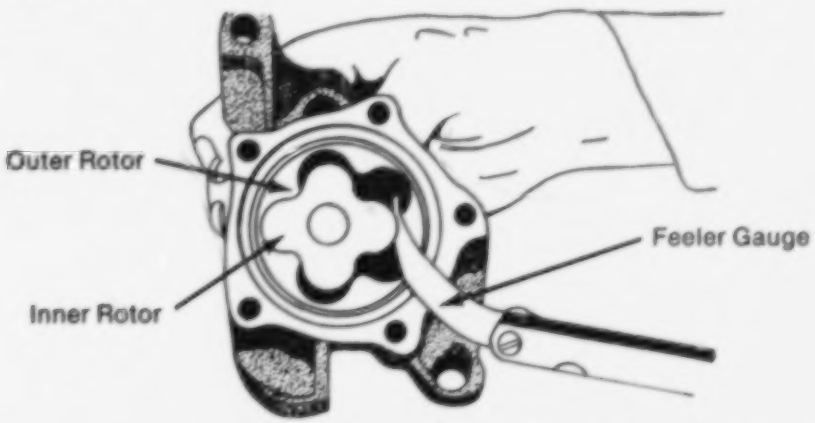
O. Install inner rotor into pump body

JOB SHEET #10

P. Measure clearance between inner and outer rotor (Figure 133)

(NOTE: Replace the pump if clearance exceeds service manual specifications.)

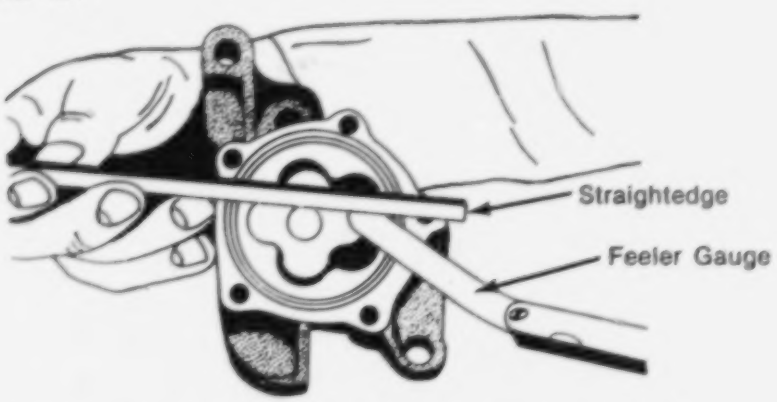
FIGURE 133



Q. Place straightedge across face of pump body between bolt holes (Figure 134)

(NOTE: If an 0.004-inch or more feeler gauge can be inserted between straightedge and rotors, replace the pump assembly.)

FIGURE 134



R. Inspect pressure regulator valve plunger for scoring and free operation in bore

(NOTE: Small marks may be removed with #400 grit wet or dry sandpaper.)

S. Measure free length of pressure regulator valve spring and compare with specifications

(NOTE: Reassemble the pump if measurements are within service manual specifications.)

T. Install a new oil seal in pump body groove

U. Set pump cover in place and secure with screws and lock washers

(NOTE: Prime the pump before installation by pouring oil in the inlet passage while rotating the rotor shaft.)

V. Torque screws to proper specifications

W. Clean work area; clean and put away all tools and equipment

III. Procedure to disassemble, clean, and inspect a gear-type pump

A. Remove pump cover attaching screws

B. Remove pump cover (See Figure 135)

(NOTE: The pump cover may have a gasket, O-ring seal, or a metal-to-metal seal, depending on the manufacturer.)

C. Mark gear teeth so that they may be reassembled with the same teeth indexing

D. Remove drive gear and shaft from pump body

E. Remove idler gear from pump body

F. Remove pressure regulator valve retaining pin, pressure regulator valve, and related parts

G. Remove pump pickup screen

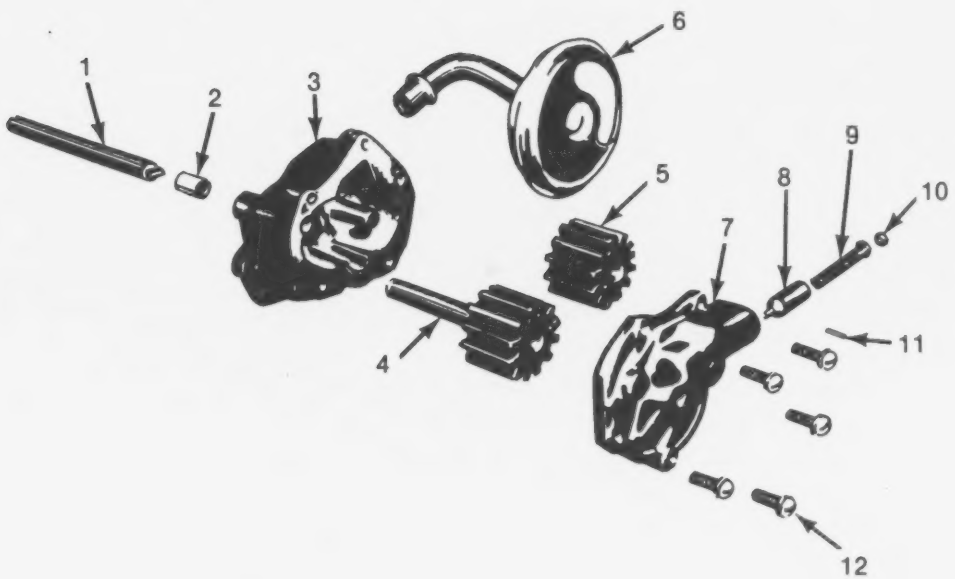
1. Place pump body in a soft-jawed vise

JOB SHEET #10

2. Pull or tap pickup screen and pipe out of body

(CAUTION: Do not disturb the pickup screen on the pipe. This is serviced as an assembly only.)

FIGURE 135



1) Shaft extension
2) Shaft coupling
3) Pump body
4) Drive gear and shaft
5) Idler gear
6) Pickup screen and pipe
7) Pump cover
8) Pressure regulator valve
9) Pressure regulator spring
10) Washer
11) Retaining pin
12) Screws

H. Clean and inspect oil pump

1. Wash all parts in cleaning solvent and dry with compressed air

(CAUTION: Always wear eye protection when using compressed air.)

2. Inspect pump body and cover for cracks or excessive wear

3. Inspect pump gears for damage or excessive wear

4. Check drive gear shaft for looseness in pump body

JOB SHEET #10

5. Inspect pickup screen and pipe assembly for damage

6. Check pressure regulator valve for fit

(NOTE: If the pump gears or body are damaged or worn, replacement of the entire assembly is necessary.)

I. Assemble the gear-type pump

1. Install pressure regulator valve and related parts

2. Install drive gear and shaft into pump body

3. Install idler gear into pump body in same direction as removed while aligning indexing marks

4. Install pump cover, using appropriate gasket or seal as necessary

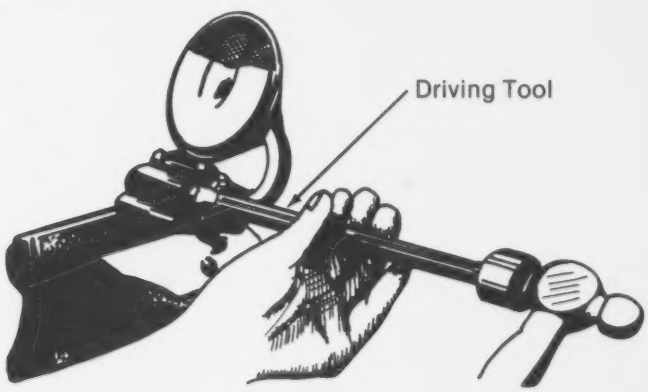
5. Torque cover attaching screws to specifications

6. Turn drive shaft by hand to check for smooth operation

7. Install new pickup screen and pipe assembly (Figure 136)

(NOTE: Replace the pickup screen and pipe assembly with a new one because the press fit may leak when installed the second time and will cause low oil pressure.)

FIGURE 136



J. Clean work area; clean and put away all tools and equipment

CLEANING, INSPECTING, AND RECONDITIONING
GASOLINE ENGINES
UNIT III

JOB SHEET #11 — REMOVE PISTON RING RIDGE FROM CYLINDER

I. Equipment and materials

A. Ridge remover tool with instructions for use

B. Carbon scraper

C. Eye protection

D. Basic hand-tool set

E. Shop cloth

F. Light motor oil

II. Procedure

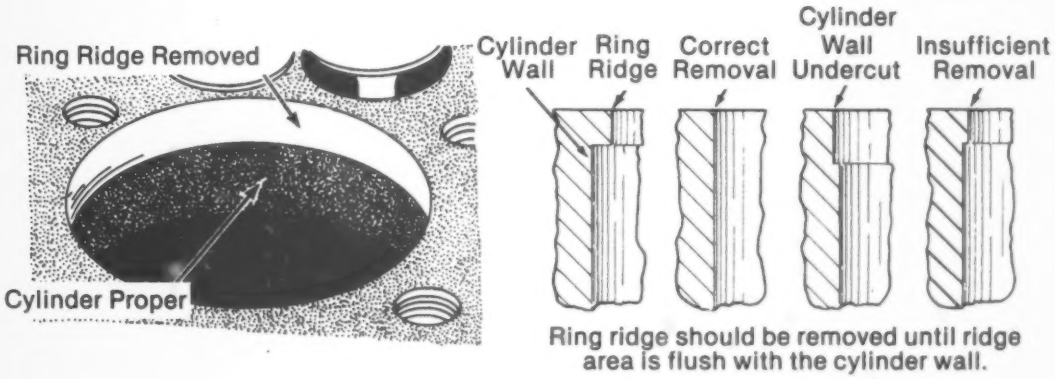
A. Rotate crankshaft until piston is at bottom dead center

B. Stuff a cloth into cylinder on top of piston

(NOTE: The cloth is used to catch metal cuttings from the ridge remover tool.)

C. Clean carbon deposits from ridge area (Figure 137)

FIGURE 137



Ring ridge should be removed until ridge area is flush with the cylinder wall.

D. Blow carbon from cylinder

E. Wipe a film of light motor oil on cylinder walls

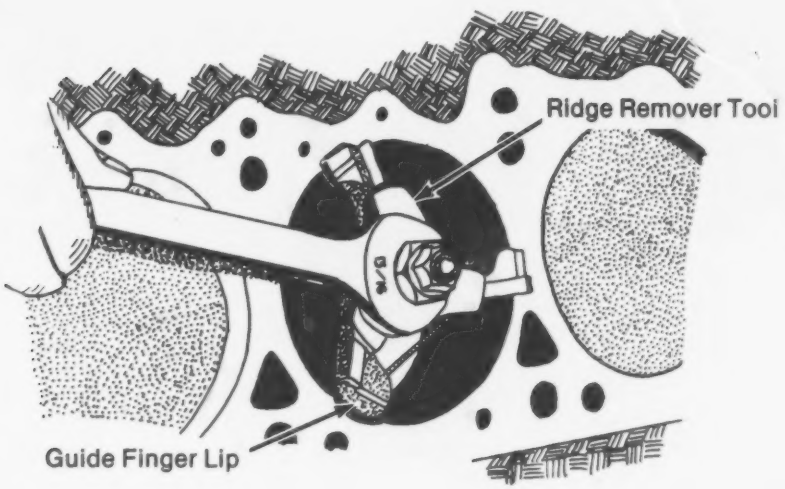
JOB SHEET #11

F. Adjust ridge remover tool to be slightly smaller than cylinder diameter

(NOTE: There are several types of ridge remover tools. Be sure to read carefully and follow the instructions for the particular tool you are using.)

G. Place ridge remover into cylinder until it seats on its guides; adjust cutting blade according to instructions (Figure 138)

FIGURE 138



H. Turn ridge remover clockwise by hand to cut out ridge

(CAUTION: Do not remove the ridge below the surface of the cylinder wall or scratch the cylinder wall where the piston ring travels.)

I. Remove ridge remover from cylinder

J. Remove cloth from cylinder

(NOTE: The piston can now be removed without damage to the ring lands.)

K. Clean work area; clean and put away all tools and equipment

CLEANING, INSPECTING, AND RECONDITIONING GASOLINE ENGINES
UNIT III

JOB SHEET #12 — MEASURE A CYLINDER FOR TAPER, WEAR, AND OUT-OF-ROUND

I. Equipment and materials

- A. Cylinder gauge
- B. Micrometer set
- C. Clean shop towel
- D. Engine oil
- E. Appropriate service manual

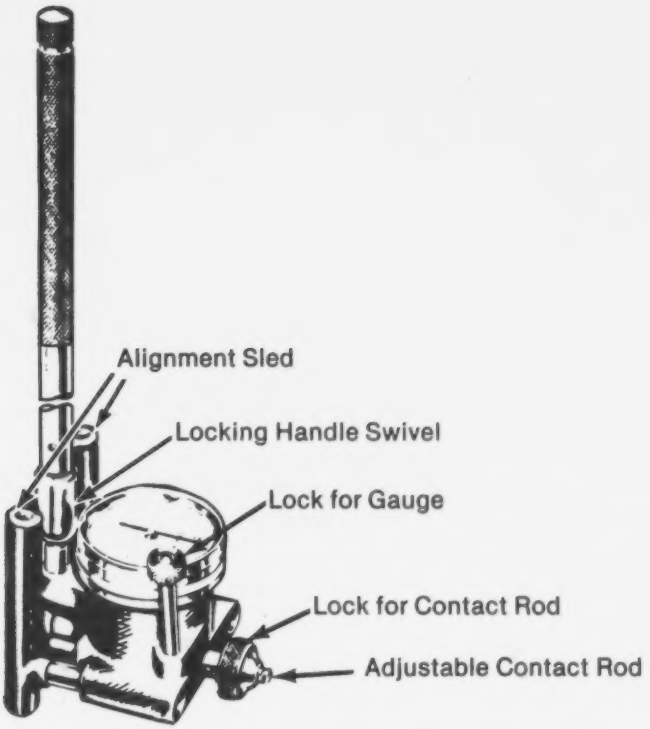
II. Procedure

- A. Clean cylinder thoroughly
- B. Set up cylinder gauge (See Figure 139)
  1. Attach handle and adjust so that upper end swings over meter
  2. Loosen contact rod lock
  3. Adjust rod to slightly larger than cylinder diameter; lock

     (NOTE: Contact rod assortment may be stored in end of the handle.)

4. Loosen gauge lock

FIGURE 139



C. Check cylinder for taper (See Figure 140)

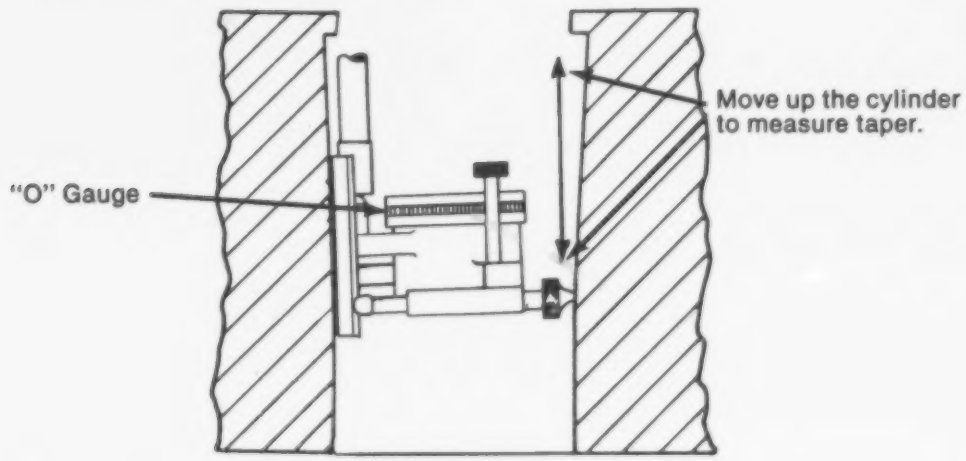
1. Place gauge in cylinder
2. Align gauge in cylinder so that gauge sled contacts cylinder wall the full length of both runners
3. Slide gauge down cylinder until contact rod is just at lower piston ring travel
4. Set dial at zero
5. Move gauge slowly up cylinder until contact rod is at uppermost piston ring travel

JOB SHEET #12

6. Take meter reading

(NOTE: This reading indicates the cylinder taper. Refer to manufacturer's specifications for allowable cylinder taper.)

FIGURE 140



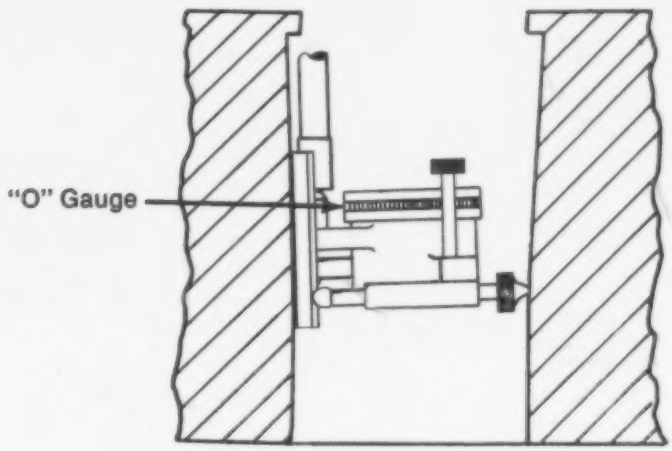
D. Check cylinder wear

1. Set gauge below lower piston ring travel

(NOTE: This area will show very little, if any, cylinder wear, so the gauge can be adjusted to original cylinder size at this position.)

2. Set dial at zero (Figure 141)

FIGURE 141



3. Move gauge up cylinder until it just reaches uppermost piston ring travel

4. Take dial reading

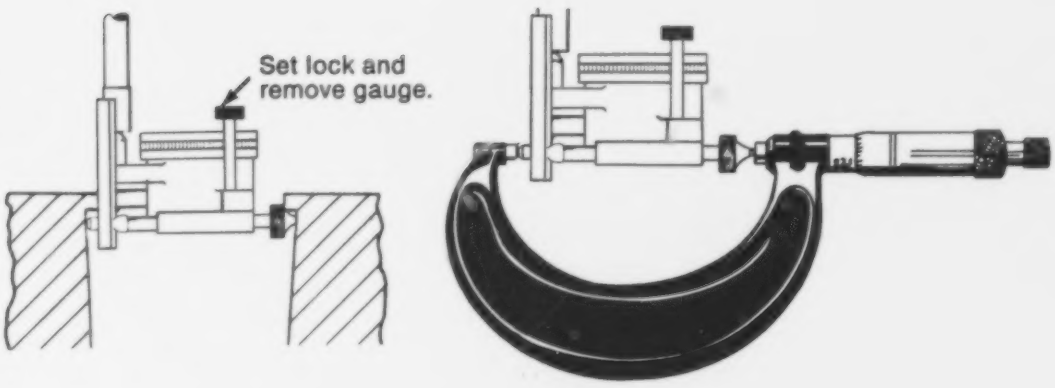
(NOTE: Because the uppermost piston ring travel is the place of greatest wear, the gauge will read total cylinder wear. Refer to manufacturer's specifications for allowable cylinder wear.)

JOB SHEET #12

5. Set gauge lock and remove gauge from cylinder; measure worn diameter with micrometer (Figure 142)

   (NOTE: Compare this reading with measurement of the piston skirt for piston clearance.)

FIGURE 142



E. Check cylinder for out-of-round condition (See Figure 143)

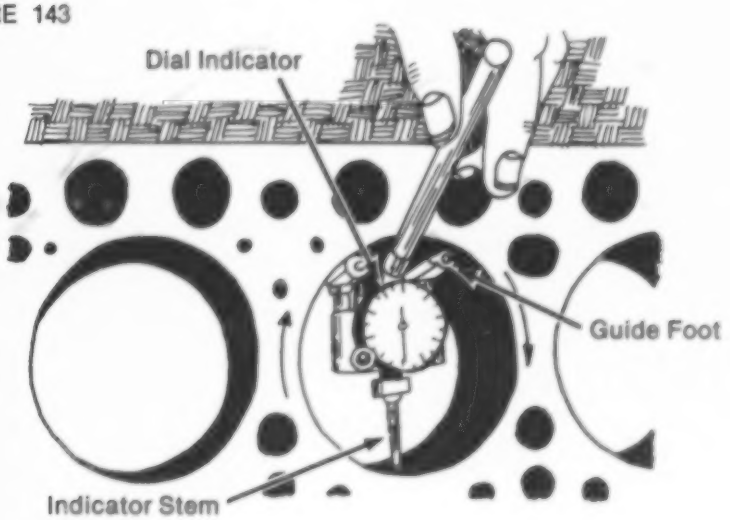
   1. Position gauge approximately halfway down piston ring travel in cylinder

   2. Set dial at zero

3. Rotate gauge around cylinder one complete turn, taking care to keep the gauge sled seated at all times

   (NOTE: The total variation of readings indicates the out-of-round condition of the cylinder. Refer to manufacturer's specifications for allowable variation.)

FIGURE 143



F. Clean work area; clean and put away all tools and equipment

CLEANING, INSPECTING, AND RECONDITIONING
GASOLINE ENGINES
UNIT III

JOB SHEET #13 — HONE A CYLINDER WITH A GLAZE-BREAKER HONE

I. Equipment and materials

A. Glaze-breaker hone

B. Drill motor

C. Cutting oil

D. Detergent and water solution

E. Eye protection

F. Scrub brush

II. Procedure

A. Protect crankshaft and main bearings if shaft has not been removed

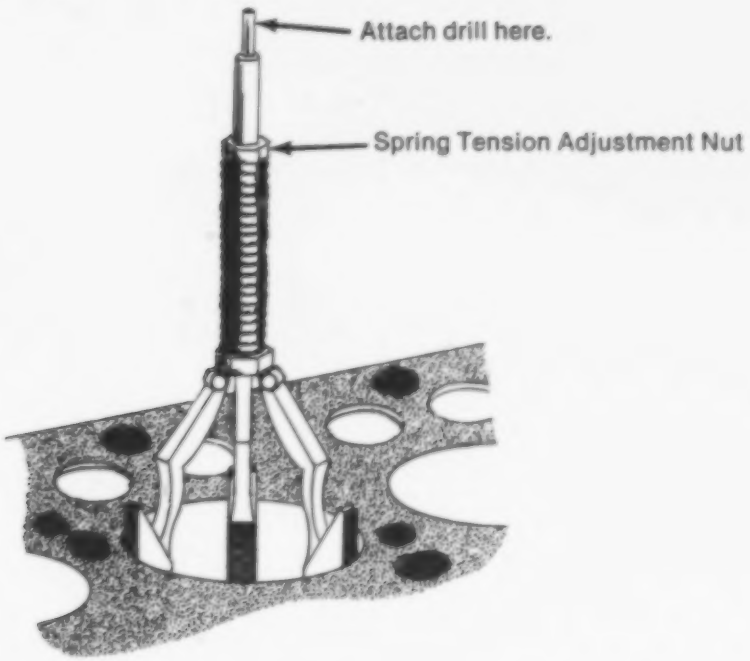
B. Clean cylinder

(NOTE: Ring ridge should have already been removed.)

JOB SHEET #13

C. Place hone in cylinder and adjust spring tension to a light-to-medium load if the hone is adjustable (Figure 144)

FIGURE 144



D. Connect drill motor to hone

(NOTE: A slow drill speed is desirable to control the hone and obtain desired results.)

E. Remove hone from cylinder, being careful to collapse stones away from cylinder wall

F. Soak hone and stones with cutting oil

G. Reinstall hone into cylinder

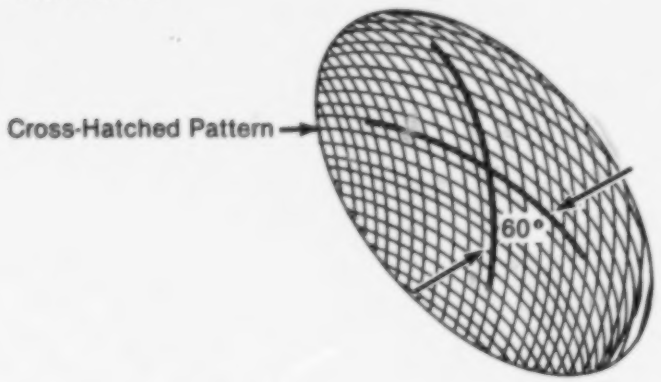
H. Hold hone and drill motor in alignment with center line of cylinder; switch on motor

JOB SHEET #13

I. Move hone up and down cylinder at a rate that will produce a cross-hatched pattern on cylinder wall (Figure 145)

(CAUTION: Do not let the hone travel too deep and catch in the main bearing webbing or come out of the top of the cylinder. The hone and operator may both receive severe damage.)

FIGURE 145



J. Hone cylinder only enough to remove glazed surface

K. Remove hone

(NOTE: Be careful not to scrub the stone against the walls. It would cause vertical marks.)

L. Wash cylinder walls thoroughly several times with soap, water, and scrub brush to remove all cuttings from honing process

(CAUTION: Do not use solvent to clean cylinder walls.)

M. Dry cylinder immediately and apply oil to newly honed surface

N. Clean work area; clean and put away all tools and equipment

CLEANING, INSPECTING, AND RECONDITIONING
GASOLINE ENGINES
UNIT III

JOB SHEET #14 — CLEAN CYLINDER HEAD SURFACE AND CHECK FOR WARPAGE

I. Equipment and materials

A. Fine-cut file (longer than block width)

B. Straightedge

C. Feeler gauge set, 0.001-inch to 0.006-inch

D. Gasket scraper

E. Eye protection

F. Shop towels

II. Procedure

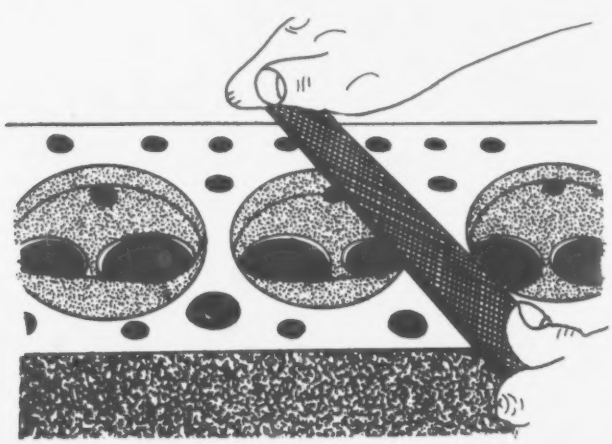
A. Position cylinder block so that head mating surface is almost horizontal

B. Clean surface with a gasket scraper

C. Remove nicks on cleaned surface with fine-cut file (Figure 146)

(NOTE: Make sure that only nicks are removed. The general condition of the surface should not be altered with a file.)

FIGURE 146



JOB SHEET #14

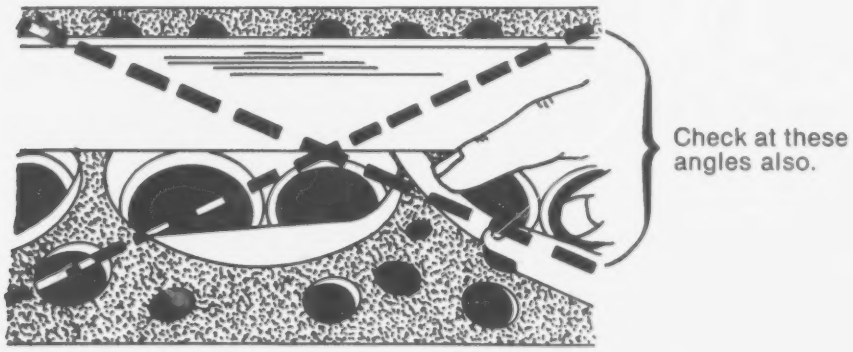
D. Wipe surface clean with shop towel

E. Position straightedge lengthwise of block

F. Check for warpage by placing a 0.001-inch feeler gauge between block and straightedge (Figure 147)

(NOTE: If at any position the gauge can be pulled from between the block and straightedge without dragging on the straight edge, try the next larger gauge. Continue until the gauge binds. If gauge thickness is more than 0.002-inch, the surface will require machining.)

FIGURE 147



G. Make several checks across the block, both lengthwise and crosswise

H. Clean work area; put away tools and equipment

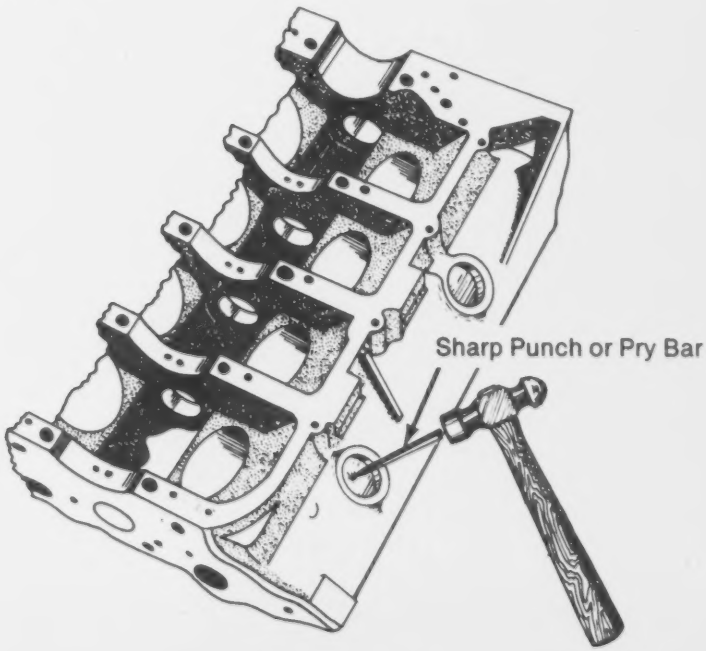
CLEANING, INSPECTING, AND RECONDITIONING
GASOLINE ENGINES
UNIT III

JOB SHEET #15 — REMOVE AND REPLACE A CYLINDER BLOCK CORE PLUG

I. Equipment and materials
   - A. Hammer
   - B. Pointed pry bar
   - C. Nonhardening sealer
   - D. Driving tool to fit core plug size
   - E. Eye protection
   - F. Wire brush
   - G. Flat-faced punch

II. Procedure
   - A. Remove old core plug
     1. Put on eye protection
     2. Drive sharp end of pry bar through center of plug
     3. Pry plug out with bar (Figure 148)

FIGURE 148



JOB SHEET #15

B. Clean sediment from water jacket behind plug hole

C. Clean sealing surface of core hole with wire brush or other appropriate tool

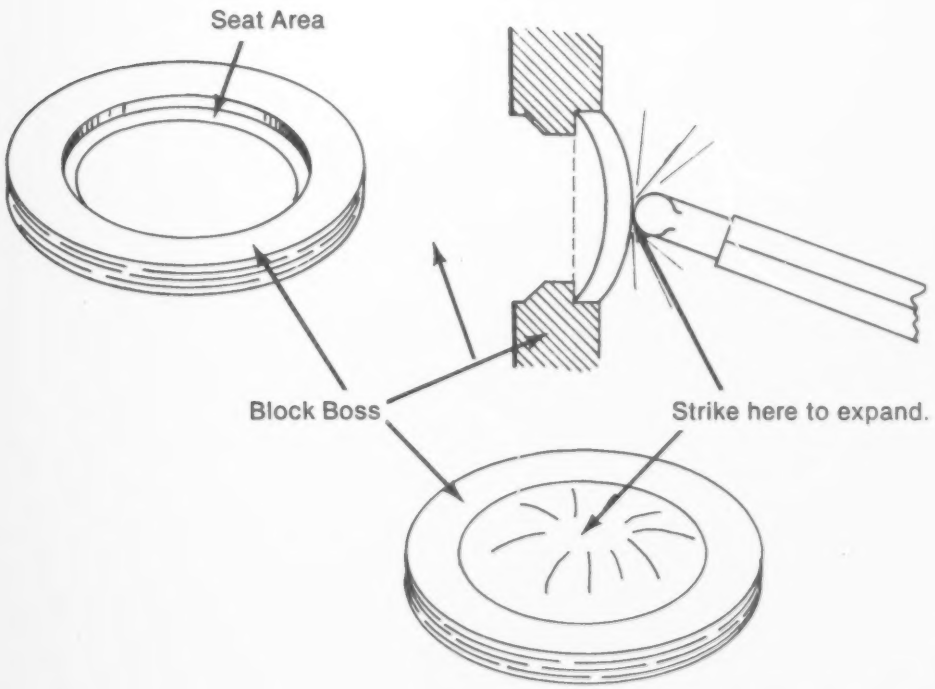
D. Coat sealing edge of new core plug with nonhardening sealer

E. Place core plug in hole in block

F. Drive plug into place with appropriate driver

(NOTE: When using the expansion disc-type plug, place the plug in the hole against the seat and then expand the plug by striking the plug in the center with a flat-faced punch to partially remove the cup shape of the plug. See Figure 149.)

FIGURE 149



CLEANING, INSPECTING, AND RECONDITIONING GASOLINE ENGINES UNIT III

TEST

NAME _____ SCORE _____

1. Match to their correct definitions terms associated with gasoline engines. Write the correct numbers in the blanks. Terms and definitions are continued on the next two pages.

_____a.	Shaft in engine that operates valves through a series of lobes	1. Valve train
_____b.	Number of degrees of crankshaft rotation while valve is open	2. Valve lasher or clearance adjustment
_____c.	Distance valve moves from closed to full-open	3. Cylinder head
_____d.	Valve-operating mechanism of engine	4. Bore
_____e.	Camshaft located in cylinder head or heads	5. I-head
_____f.	That part of engine that encloses cylinder bores and contains water jacket and sometimes valves	6. Camshaft
_____g.	Cylindrical part of engine that rests on a cam of the camshaft so that valve is opened as cam rotates	7. Bushing
_____h.	Looseness designed into valve train so that valve will seat properly	8. Bearing
_____i.	Engine in which cylinder head and valves are over the cylinder	9. Overhead camshaft
_____j.	Surface that supports a moving load with minimum drag	10. Cam lift
_____k.	Notch or lip on a bearing shell used to locate bearing correctly during assembly and operation	11. Bearing tang
_____l.	Diameter of a hole	12. Valve lifter
_____m.	Spacing device; usually a sleeve with a bearing surface on the inside	13. Cam duration

TEST

_____n. Portion of crankshaft to which connecting rod fastens

_____o. Rotating gear that does not transfer a load

_____p. Slight distortion that holds bearing shell in place as engine operates

_____q. Surface on which a bearing operates

_____r. Bearing in back of crankshaft that supports front of clutch shaft

_____s. Round, weighted device attached to front of crankshaft to minimize torsional (twisting) vibration of shaft

_____t. Small-sized plastic thread for measuring clearances

_____u. Combustion gases that slip past piston and rings to get into crankcase

_____v. To roughen a piece of metal by pressing a series of crosshatched lines into the surface, thereby raising the area between these lines

_____w. Surface between piston ring grooves

_____x. Chamber between cylinder bores on a V-block engine

_____y. Sound made by a piston with excess skirt clearance as crankshaft moves across top center

_____z. Raised portion of piston head

_____aa. To size a hole to exact dimensions with a cutting tool called a reamer

_____bb. Basic engine framework to which other engine parts are attached

14. Idler gear
15. Crankpin
16. Land
17. Piston slap
18. Bearing crush
19. Blow-by
20. Pop-up
21. Pilot bearing
22. Plastigauge
23. Lifter valley
24. Knurl
25. Torsional vibration damper
26. Journal
27. Cylinder block
28. Ream

TEST

_____cc.	Expandable rotating tool with abrasive fingers turned by an electric motor; used to clean and smooth inside surface of cylinder	29. Cylinder hone
_____dd.	Lower ring or rings on a piston; designed to prevent excessive amounts of oil from working up into combustion chamber	30. Ring-expander tool 31. Ring ridge 32. Oil control ring
_____ee.	Special tool used to expand piston rings for installation on piston	
_____ff.	That portion of cylinder above the top limit of ring travel	

2. Match parts of the valve train to their correct functions. Write the correct numbers in the blanks.

_____a.	Opens and closes intake and exhaust ports connected to cylinder	1. Rocker arm 2. Camshaft
_____b.	Forces valve to close	3. Crankshaft gear
_____c.	Changes direction of motion in valve train and pushes valve off its seat	4. Lifter
_____d.	Transmits motion from lifter to rocker arm	5. Valve spring
_____e.	Rides along cam lobe; changes rotating motion to reciprocal motion	6. Cam gear 7. Valve
_____f.	Operates valve lifters by rotating cam lobes against lifters	8. Push rod
_____g.	Turns camshaft and is used in timing camshaft to crankshaft	
_____h.	Drives cam gear	

3. List methods of driving the camshaft.

a. _____

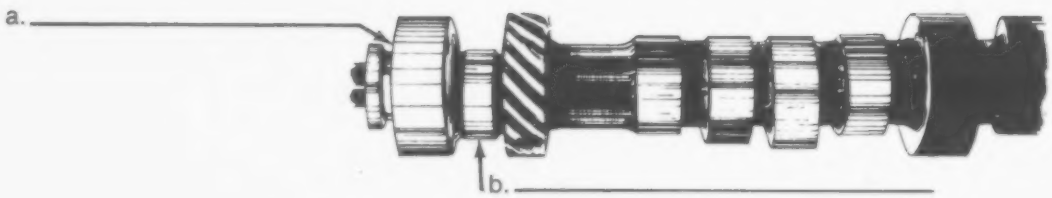
b. _____

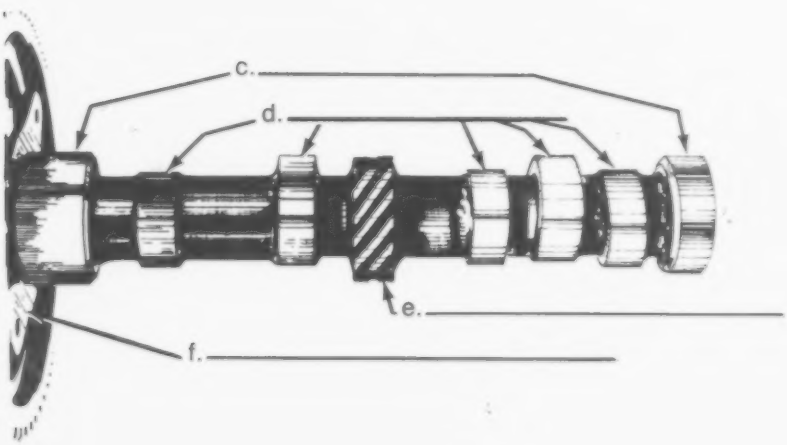
c. _____

TEST

4. Identify the parts of the camshaft illustrated below. Write the correct names in the blanks.

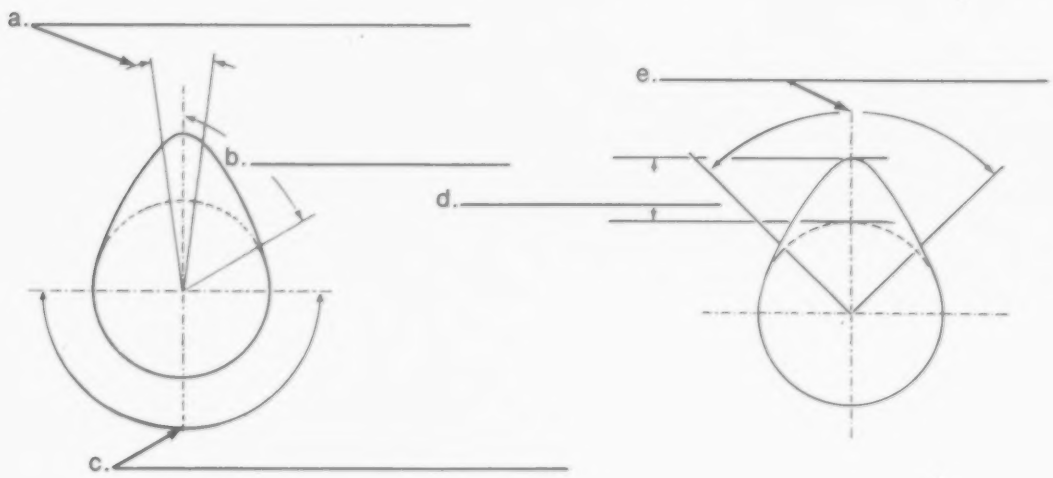
Bearing journal	**Accessory drive gear**	**Cam lobes**
Retainer plate	**Fuel pump eccentric**	**Thrust face**





TEST

5. Label the parts of the cam lobe illustrated below. Write the correct names in the blanks.



6. State types of valve lifters.

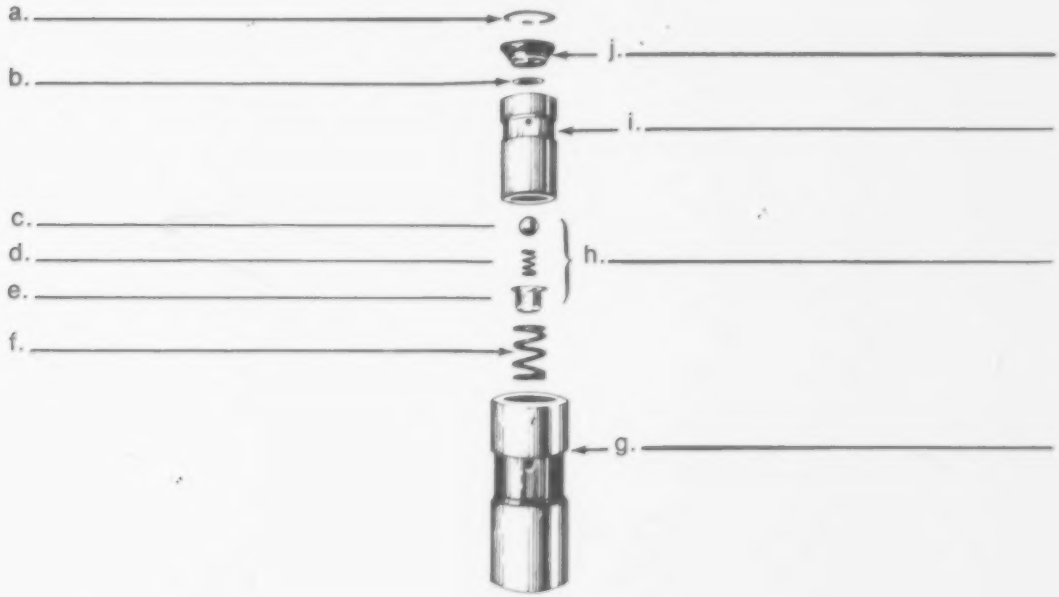
a. _____

b. _____

TEST

7. Identify the parts of the hydraulic valve lifter illustrated below. Write the correct names in the blanks.

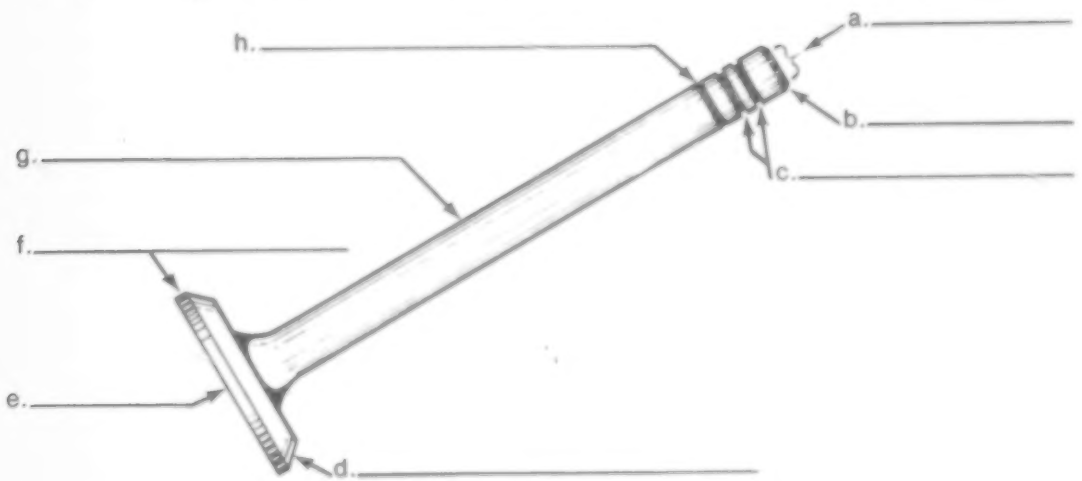
Snap ring retainer	**Push rod seat**	**Ball spring**	**Ball retainer**
Plunger	**Metering disc**	**Plunger spring**	**Body**
Ball	**Check valve assembly**		



8. Discuss operation of a hydraulic valve lifter.

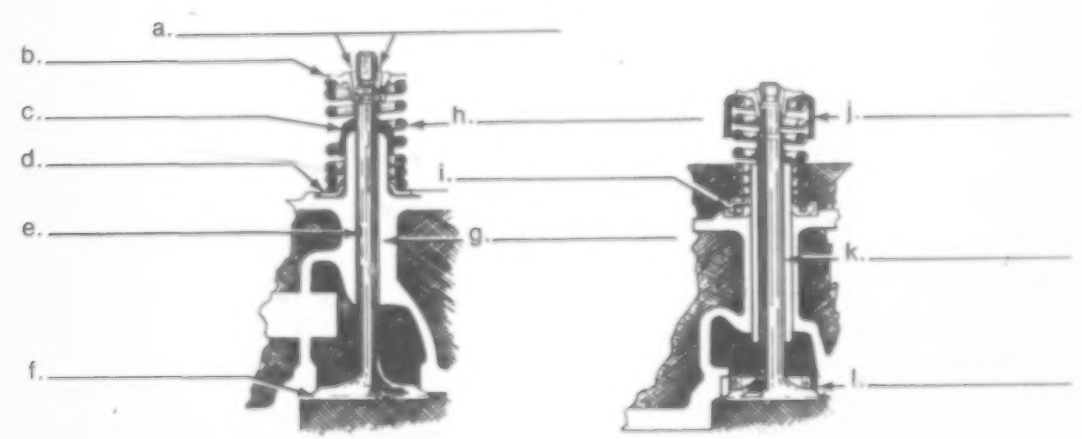
TEST

9. Label the parts of the valve illustrated below. Write the correct names in the blanks.



10. Identify the parts of the valve assembly illustrated below. Write the correct names in the blanks.

Valve	**Spring seat**	**Spring retainer**
Spring	**Oil seal**	**Valve guide (integral)**
Shield	**Rotator**	**Valve seat (insert type)**
Valve seat (integral type)	**Keepers**	**Valve guide (replaceable)**



TEST

11. Identify types of valve springs and dampering devices. Write the correct names in the blanks.

Friction damper spring
Variable rate spring
Standard spring with inner assist spring
Friction damper tube
Standard spring

a. _____

b. _____

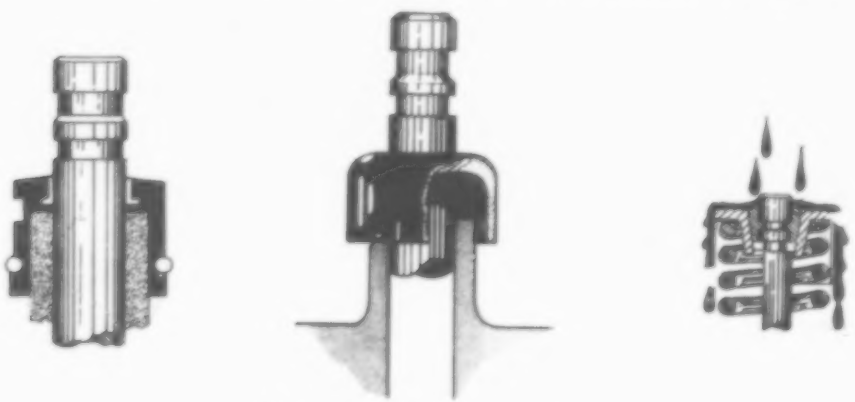
c. _____

d. _____

e. _____

TEST

12. Label types of valve stem seals illustrated below. Write the correct names in the blanks.



a. _____ b. _____ c. _____

13. Identify types of valve spring keepers. Write the correct names in the blanks.

Pin
Plain conical
Single-groove conical
Four-groove conical
Two-groove conical
Horseshoe

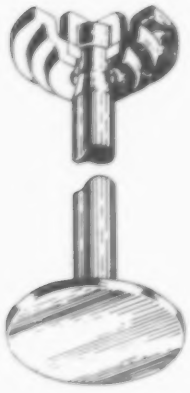
a. _____ b. _____ c. _____

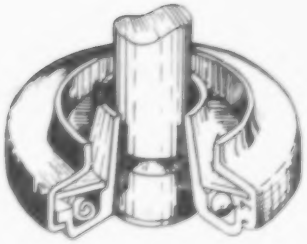
d. _____ e. _____ f. _____

TEST

14. Identify types of valve rotators. Write the correct names in the blanks.

Free **Off-center** **Positive**





a. _____ b. _____ c. _____

15. State reasons valves must seat properly.

a. _____

b. _____

16. Select from the following list major causes of valve burning. Write an "X" in the blank before each correct answer.

_____a. Water jacket clogged or distribution tube causing localized hot spots

_____b. Valve tappet clearance insufficient

_____c. Combustion chamber having carbon deposits

_____d. Valve not seating properly

_____e. Cam lobes worn

_____f. Valve seat warped from improper torquing of cylinder head

_____g. Valve guides worn

TEST

_____h. Air/fuel mixture extremely lean

_____i. Crankcase having carbon deposits

_____j. Valve springs weak or cocked

_____k. Preignition and detonation

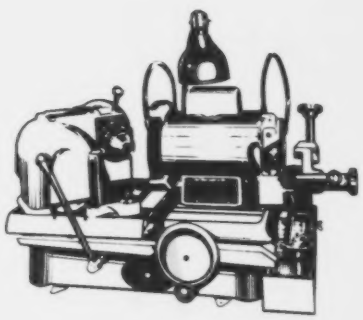
_____l. Exhaust heat riser valve stuck in closed position

_____m. Amount of air/fuel mixture insufficient

_____n. Engine overheating

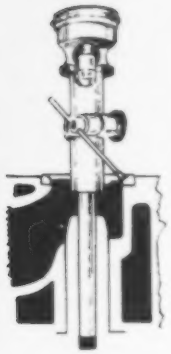
17. Identify tools used to recondition valves. Write the correct names in the blanks.

Guide cleaner
Guide reamer
Carbon brush
Drive motor (seat grinding)
Carbon scraper
Cylinder head stand
Seat grinding pilot
Valve grinding machine
Wheel holder (seat grinding)
Spring compressor
Valve seat indicator
Wheel dressing tool (seat grinding)
Valve spring tension gauge

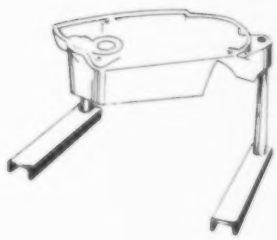


a. _____ b. _____ c. _____

TEST

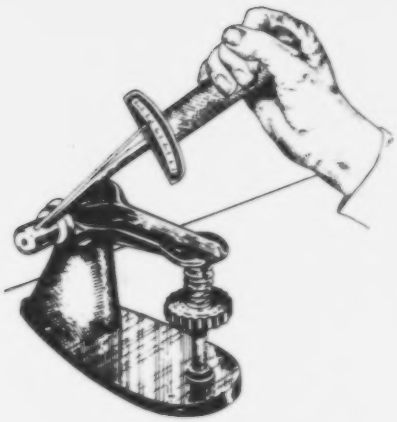


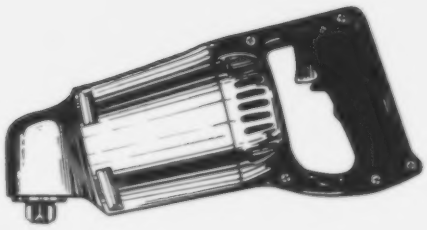
d. _____ e. _____ f. _____



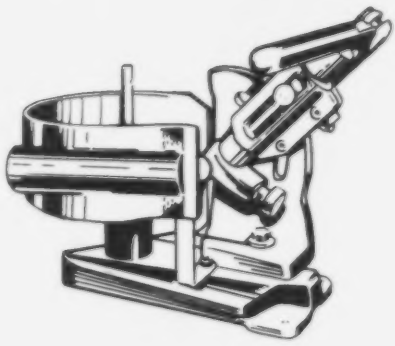
g. _____ h. _____ i. _____

TEST





j. _____ k. _____



l. _____ m. _____

18. State the purpose of the crankshaft.

_____

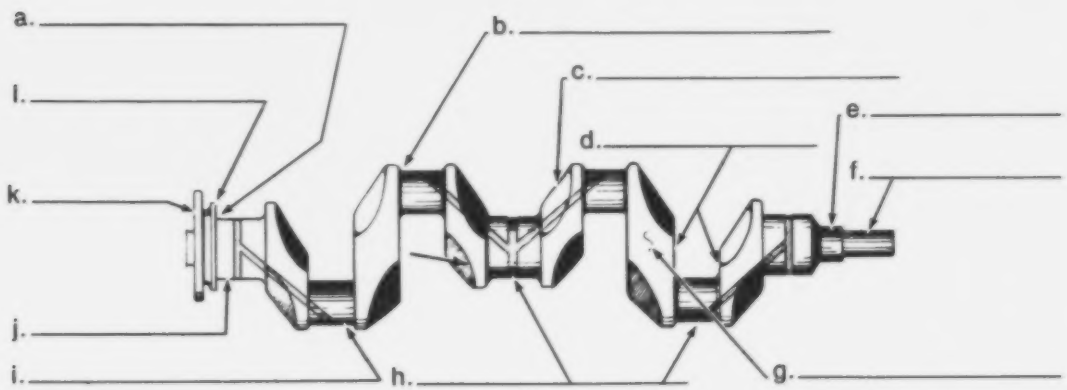
_____

_____

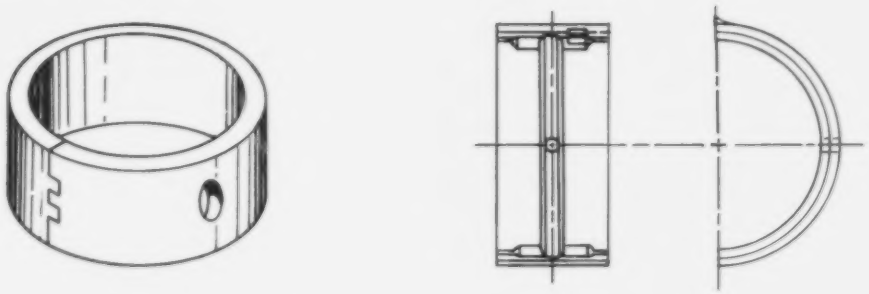
_____

TEST

19. Label the parts of the crankshaft illustrated below. Write the correct names in the blanks.



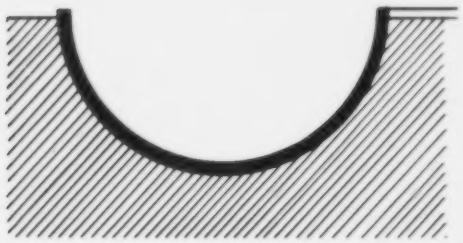
20. Label types of bearings used on the cam and crankshaft.

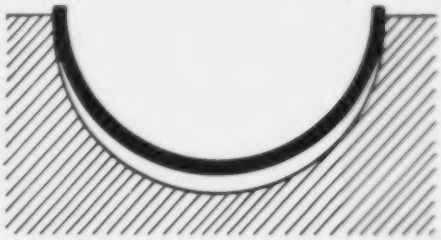


a. _____ b. _____

TEST

21. Distinguish between bearing spread and bearing crush. Write an "X" in the blank representing bearing crush.





a. _____ b. _____

22. Match bearing requirements to their correct definitions. Write the correct numbers in the blanks.

_____a.	Ability to support the severe centrifugal and combustion forces in engine	1. Wear resistance
_____b.	Wear rate hard and tough enough to maintain a long service life	2. Embedability
_____c.	Ability to permit foreign particles to become compressed into soft bearing surface to protect the smooth crankshaft	3. Load-carrying capacity
_____d.	Resistance to severe pressure and bending without failure	4. Corrosion resistance
_____e.	Ability of soft bearing surface to change to variations in shaft alignment and journal shape	5. Conformability
_____f.	Ability to resist the corrosive effect of combustion by-products	6. Fatigue resistance

TEST

23. Discuss action of lubrication oil in an insert-type bearing.

_____

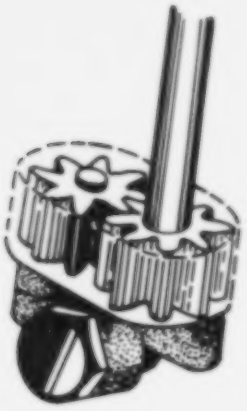
_____

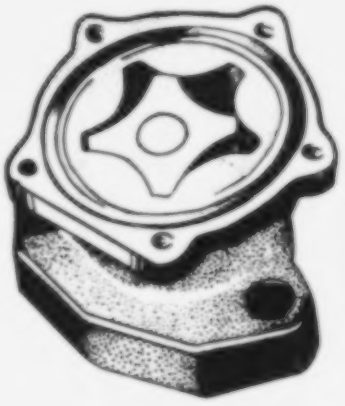
24. Distinguish between purpose of torsional vibration damper (harmonic balancer) and purpose of flywheel. Write an "F" in the blank before the statement representing purpose of flywheel.

_____a. Evens out power surges from power stroke to power stroke

_____b. Opposes crankshaft torsional vibration or twisting/untwisting action of crankshaft caused by the cylinder firing impulse

25. Label types of oil pumps illustrated below. Write the correct names in the blanks.



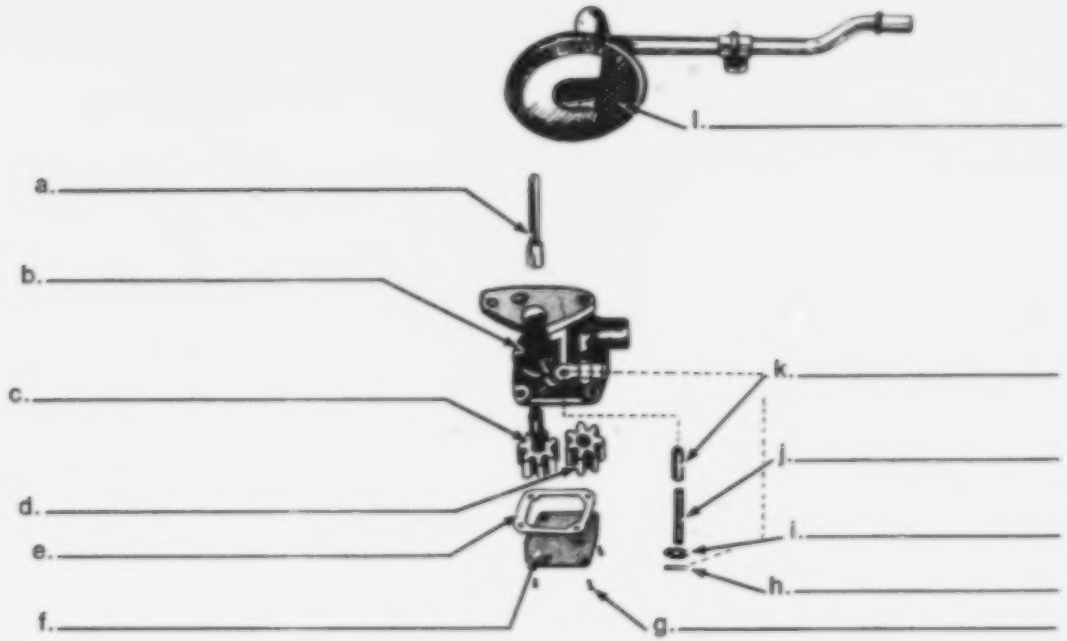


a. _____ b. _____

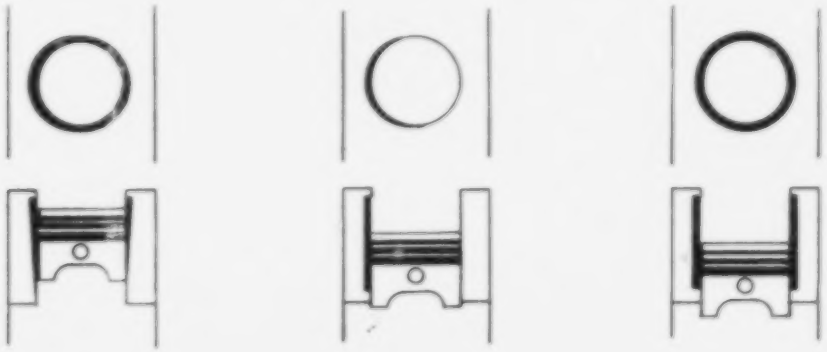
TEST

26. Identify the parts of an oil pump. Write the correct names in the blanks.

Pressure regulator valve	**Pressure regulator spring**	**Washer**
Pickup screen and pipe	**Retaining pin**	**Screws**
Extension shaft (not used on some models)	**Idler gear**	**Gasket (not used on some models)**
Drive gear and shaft	**Pump cover**	
	Pump body	



27. Label cylinder wear patterns. Write the correct names in the blanks.



a. _____ b. _____ c. _____

TEST

28. List methods of reconditioning cylinders.

    a. _____

    b. _____

    c. _____

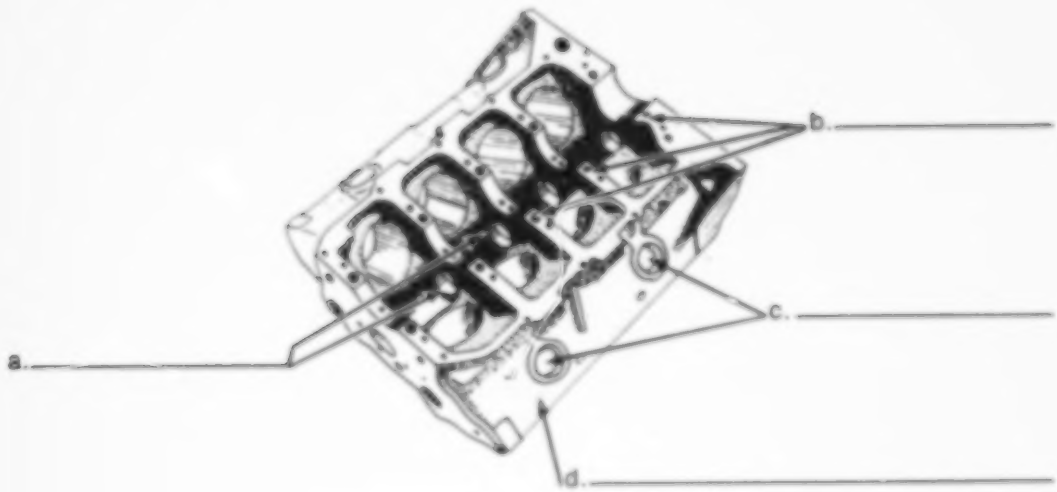
29. State types of cylinder sleeves.

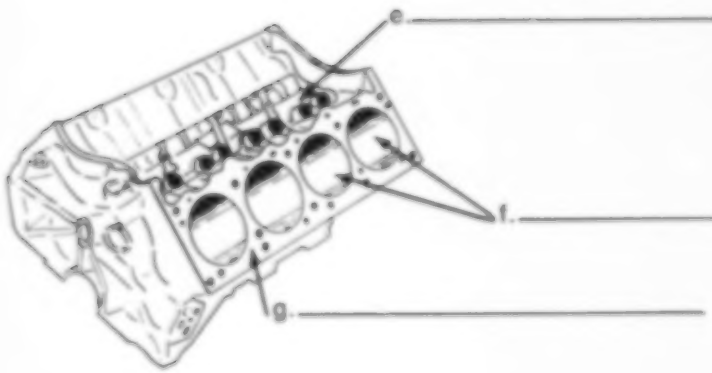
    a. _____

    b. _____

TEST

30. Label the parts of the cylinder block illustrated below. Write the correct names in the blanks.





31. Name types of cylinder block core hole plugs.

a. _____

b. _____

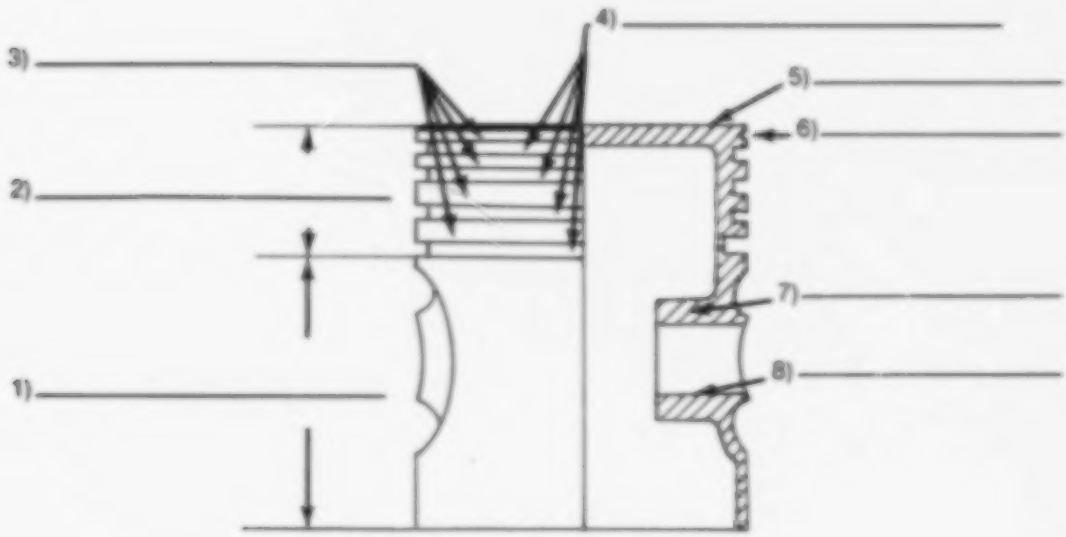
c. _____

TEST

32. Identify the parts of a piston and connecting rod assembly. Write the correct names in the blanks.

a. Piston

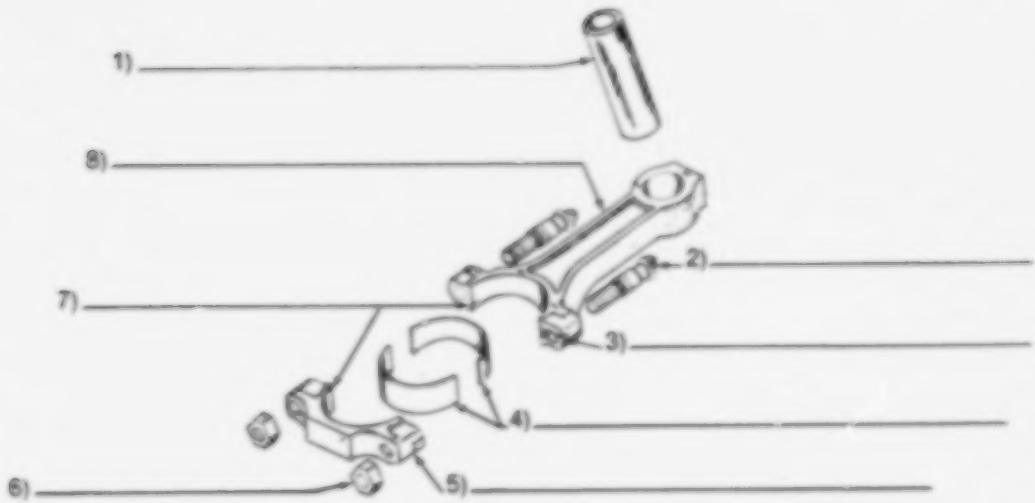
Head	**Pin bearing**	**Skirt section**
Pin boss	**Ring section**	**Ring grooves**
Ring lands		**Heat dam**



TEST

b. Connecting rod assembly

Rod	Bearing lock groove	Rod cap	Bolt
Nut	Bearing inserts	Split hole	Piston pin



33. Identify types of compression rings. Write the correct names in the blanks.

Tapered	Chamfered	Counterbored
Plain	Scraper	Center grooved

a. _____ b. _____ c. _____

d. _____ e. _____ f. _____

TEST

34. Identify types of oil rings. Write the correct names in the blanks.

Drilled **Three-piece** **Slotted**
Wedge slotted **Radius slotted**

a. _____

b. _____

c. _____

d. _____

e. _____

35. Match methods of piston heat and expansion control to their correct descriptions. Write the correct numbers in the blanks.

_____a. Groove around top of piston reduces flow of heat from piston head to piston skirt

_____b. Steel band cast into piston pin boss reduces expansion of piston skirt due to heat, and conducts heat out through pin boss

_____c. Piston skirt is ground to a cam shape and contacts only in the center when it is cold; as it heats up, it becomes round to fit cylinder more completely

_____d. T-shaped slot breaks path of heat traveling to skirt and allows for skirt expansion without increasing diameter

1. Steel band or belt
2. Heat dam
3. Cam-ground piston
4. Horizontal or vertical slot in piston skirt

TEST

36. Match piston conditions to related causes. Write the correct numbers in the blanks.

_____a.	Loose or broken piston pin lock ring	1. Piston head damage
_____b.	Cylinder detonation	2. Piston pin boss and ring land damage
_____c.	Excessive carbon deposit buildup	3. Excessively worn upper ring groove
_____d.	Misaligned connecting rod	4. Piston rings stuck in groove
_____e.	Piston improperly fitted to cylinder	5. Cracked piston skirt
		6. Piston skirt wear
_____f.	Preignition or overheated cylinder	7. Ring land damage
_____g.	Broken piston ring and preignition	8. Moderate and severe skirt damage
_____h.	Poor maintenance, poor air filtration, or service abuse	

37. State methods of lubricating cylinder walls and piston pins.

a. _____

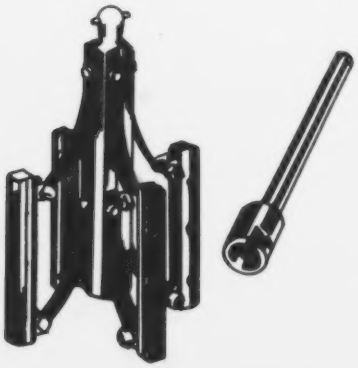
b. _____

c. _____

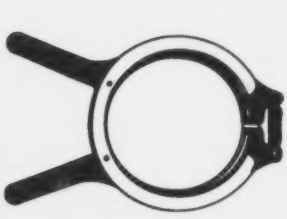
TEST

38. Identify tools and equipment used to recondition cylinders and pistons. Write the correct names in the blanks.

Cylinder gauge
Ring expander
Ring compressor
Boring hone
Glaze-breaker hone
Sleeve puller and press
Piston gauge and scale
Piston pin press
Ring groove gauge
Boring bar



a. _____ b. _____ c. _____



d. _____ e. _____ f. _____

TEST

g. _____

h. _____

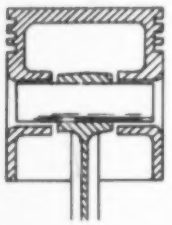
i. _____

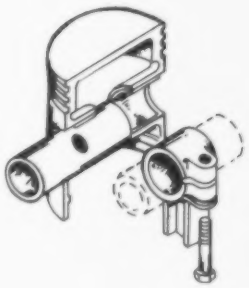
j. _____

TEST

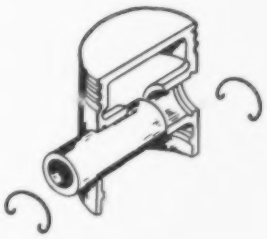
39. Identify types of piston pin locks. Write the correct names in the blanks.

Locked to connecting rod **Free floating**
Locked to piston **Press fit in rod**





a. _____ b. _____



c. _____ d. _____

(NOTE: Test question 40 lists the job sheets. They are an important part of this test. If they have not been completed, check with your instructor.)

40. Demonstrate the ability to

a. Inspect timing gears and measure timing chain for stretch and camshaft end play.

b. Inspect camshaft.

c. Clean and inspect hydraulic lifters.

d. Disassemble, clean, and inspect cylinder head assembly.

e. Recondition cylinder head.

f. Check main bearing bore alignment.

TEST

g. Measure and inspect a crankshaft.

h. Fit a crankshaft bearing with Plastigauge.

i. Install a rear main bearing seal.

j. Disassemble, clean, and inspect an oil pump.

k. Remove piston ring ridge from cylinder.

l. Measure a cylinder for taper, wear, and out-of-round.

m. Hone a cylinder with a glaze-breaker hone.

n. Clean cylinder head surface and check for warpage.

o. Remove and replace a cylinder block core plug.

CLEANING, INSPECTING, AND RECONDITIONING GASOLINE ENGINES
UNIT III

ANSWERS TO TEST

1.	a.	6	i.	5	q.	26	y.	17
	b.	13	j.	8	r.	21	z.	20
	c.	10	k.	11	s.	25	aa.	28
	d.	1	l.	4	t.	22	bb.	27
	e.	9	m.	7	u.	19	cc.	29
	f.	3	n.	15	v.	24	dd.	32
	g.	12	o.	14	w.	16	ee.	30
	h.	2	p.	18	x.	23	ff.	31

2.	a.	7	e.	4
	b.	5	f.	2
	c.	1	g.	6
	d.	8	h.	3

3. a. Gear
   b. Chain
   c. Belt

4.	a.	Thrust face	d.	Cam lobes
	b.	Fuel pump eccentric	e.	Accessory drive gear
	c.	Bearing journal	f.	Retainer plate

ANSWERS TO TEST

5. a. Nose
   b. Ramp
   c. Heel
   d. Valve lift
   e. Valve duration

6. a. Solid
   b. Hydraulic

7. a. Snap ring retainer
   b. Metering disc
   c. Ball
   d. Ball spring
   e. Ball retainer
   f. Plunger spring
   g. Body
   h. Check valve assembly
   i. Plunger
   j. Push rod seat

8. Discussion should include the following
   a. Engine oil is fed into lifter through holes in undercut area of lifter body
   b. Oil under pressure inside plunger pushes check valve open and fills area between bottom of plunger and body, causing them to expand and to keep zero clearance in the valve linkage when lifter is on heel portion of cam lobe
   c. Oil is trapped between plunger and body to maintain plunger position in lifter body as lifter rides up cam lobe

9. a. Lift area
   b. Chamfer
   c. Lock grooves
   d. Face
   e. Head
   f. Margin
   g. Stem
   h. Seal groove (some types)

ANSWERS TO TEST

10. a. Keepers
    b. Spring retainer
    c. Oil seal
    d. Spring seat
    e. Valve
    f. Valve seat (integral type)
    g. Valve guide (integral)
    h. Spring
    i. Rotator
    j. Shield
    k. Valve guide (replaceable)
    l. Valve seat (insert type)

11. a. Friction damper spring
    b. Friction damper tube
    c. Standard spring
    d. Variable rate spring
    e. Standard spring with inner assist spring

12. a. Teflon cup
    b. Cup or umbrella
    c. O-ring

13. a. Plain conical
    b. Horseshoe
    c. Four-groove conical
    d. Two-groove conical
    e. Pin
    f. Single-groove conical

14. a. Free
    b. Positive
    c. Off-center

15. a. To make an airtight seal on the combustion chamber
    b. To enable the valve to cool

ANSWERS TO TEST

16. a, b, c, d, f, g, h, j, k, l, n

17.

a.	Valve grinding machine		h.	Cylinder head stand	
b.	Wheel holder (seat grinding)		i.	Guide cleaner	
c.	Carbon scraper		j.	Valve spring tension gauge	
d.	Valve seat indicator		k.	Drive motor (seat grinding)	
e.	Carbon brush		l.	Guide reamer	
f.	Spring compressor		m.	Wheel dressing tool (seat grinding)	
g.	Seat grinding pilot				

18. Purpose of the crankshaft — To change reciprocating motion of the pistons to rotating motion

19.

a.	Thrust bearing area		g.	Counterweight	
b.	Crankpin fillet		h.	Oil passages	
c.	Crank web		i.	Crankpin (connecting rod journal)	
d.	Crank cheek		j.	Main bearing journal	
e.	Crankshaft gear		k.	Flywheel flange	
f.	Pulley and damper mounting area		l.	Oil slinger	

20. a. Sleeve friction bearing

b. Split sleeve friction bearing

21. a

22.

a.	3	d.	6
b.	1	e.	5
c.	2	f.	4

ANSWERS TO TEST

23. Discussion should include the following — Keeps bearing and rotating shaft journal separated by a film of oil so that there is no actual metal-to-metal contact

24. a

25. a. Gear
    b. Rotor

26. a. Extension shaft (not used on some models)
    b. Pump body
    c. Drive gear and shaft
    d. Idler gear
    e. Gasket (not used on some models)
    f. Pump cover
    g. Screws
    h. Retaining pin
    i. Washer
    j. Pressure regulator spring
    k. Pressure regulator valve
    l. Pickup screen and pipe

27. a. Taper
    b. Out-of-round
    c. Normal wear

28. a. Honing
    b. Boring
    c. Replacing sleeve

ANSWERS TO TEST

29. a. Dry
    b. Wet

30. a. Camshaft bore
    b. Main bearing support
    c. Core holes
    d. Water jacket
    e. Valve lifter chamber
    f. Cylinders
    g. Head mating surface

31. a. Cup
    b. Expansion cup
    c. Expansion disc

32. a. Piston
        1) Skirt section
        2) Ring section
        3) Ring lands
        4) Ring grooves
        5) Head
        6) Heat dam
        7) Pin boss
        8) Pin bearing
    b. Connecting rod assembly
        1) Piston pin
        2) Bolt
        3) Spit hole
        4) Bearing inserts
        5) Rod cap
        6) Nut
        7) Bearing lock groove
        8) Rod

33. a. Scraper
    b. Center grooved
    c. Chamfered
    d. Tapered
    e. Counterbored
    f. Plain

ANSWERS TO TEST

34. a. Slotted
    b. Three-piece
    c. Wedge slotted
    d. Radius slotted
    e. Drilled

35. a. 2
    b. 1
    c. 3
    d. 4

36. a. 2
    b. 8
    c. 4
    d. 6
    e. 5
    f. 1
    g. 7
    h. 3

37. a. Splash system
    b. Spit oil hole in rod
    c. V-groove in rod

38. a. Glaze-breaker hone
    b. Boring bar
    c. Boring hone
    d. Ring expander
    e. Piston gauge and scale
    f. Ring compressor
    g. Cylinder gauge
    h. Sleeve puller and press
    i. Piston pin press
    j. Ring groove gauge

39. a. Press fit in rod
    b. Locked to connecting rod
    c. Locked to piston
    d. Free floating

40. Performance skills evaluated to the satisfaction of the instructor

CLEANING, INSPECTING, AND RECONDITIONING DIESEL ENGINES UNIT IV

UNIT OBJECTIVE

After completing this unit, the student should be able to clean, inspect, and recondition a diesel engine. The student will show this knowledge by completing job sheets and unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match terms associated with diesel engines to their correct definitions.
2. List major parts of a cylinder head assembly.
3. Identify primary parts of a valve assembly.
4. Name types of valve rotators.
5. Match engine head types to valve arrangements.
6. Name locations of turbulence chambers in an engine.
7. Label types of engine valves.
8. Identify primary parts of a piston and connecting rod assembly.
9. State functions of the piston.
10. Label main parts of a piston.
11. State functions of piston rings.
12. Name types of piston rings.
13. Select from a list possible causes of high oil consumption and blow-by.
14. Label types of piston pins.
15. State reason for markings on connecting rod, piston, and bearing cap.
16. Name parts actuated by the camshaft on some diesel engines.
17. Label primary parts of a camshaft.
18. Label parts in a valve train.

OBJECTIVE SHEET

19. Explain valve timing on a four-cycle engine.
20. Name gears found in a typical gear train.
21. Name gears that are marked in the gear train to ensure correct valve timing.
22. Describe the purpose of through bolts on an A-frame engine.
23. State ways cylinder blocks may be constructed.
24. State advantages of a removable cylinder liner.
25. State advantages of wet and dry liners.
26. Identify parts of a crankshaft.
27. State factors that influence crankshaft design.
28. Match number of cylinders in engine to arrangement of crankshaft throws.
29. State ways crankshaft balance is maintained.
30. Explain how crankshaft and surrounding parts are lubricated.
31. Distinguish between a bushing and a bearing.
32. Name types of bearing locks.
33. Distinguish between bearing crush and bearing spread.
34. State the purpose of bearing oil grooves.
35. Select from a list engine indications of bearing failure.
36. State functions of the flywheel.
37. Demonstrate the ability to
    a. Remove, inspect, and install a cylinder head.
    b. Disassemble and service a valve train.
    c. Service valve guides, valve seats, valve seat inserts, and assemble valve train.
    d. Service piston and install piston rings.
    e. Service piston pin and connecting rod.

OBJECTIVE SHEET

f. Install precision-insert connecting-rod bearings.

g. Remove, service, and install a camshaft.

h. Adjust valve clearance on a valve-in-head engine.

i. Inspect, remove, and replace a cylinder liner.

j. Disassemble, inspect, and replace crankshaft assembly and engine bearings.

CLEANING, INSPECTING, AND RECONDITIONING DIESEL ENGINES UNIT IV

SUGGESTED ACTIVITIES

I. Suggested activities

A. Check with major engine manufacturers and equipment dealers for visual aids to demonstrate diesel engine operation.

B. Obtain transparencies.

(NOTE: Transparencies are available from AGC and CIMC.)

C. Provide students with objective sheet.

D. Discuss unit and specific objectives.

E. Provide students with information and job sheets.

F. Discuss information sheet.

G. Gather equipment and materials for job sheet demonstrations.

H. Demonstrate and discuss procedures outlined in job sheets.

I. Give test.

J. Complete appropriate section of competency profiles.

(NOTE: Competency profiles are available from AGC and CIMC.)

II. Instructional materials

A. Objective sheet

B. Suggested activities

C. Information sheet

D. Transparency masters

1. TM #1 — Valve Assembly
2. TM #2 — Valve Rocker Arm Assembly
3. TM #3 — Cam Followers
4. TM #4 — Energy Cell

SUGGESTED ACTIVITIES

5. TM #5 — Valve and Fuel Injector
6. TM #6 — Valve Clearance
7. TM #7 — Valve Rotators
8. TM #8 — Valve Arrangements and Turbulence Chambers
9. TM #9 — Piston Rings
10. TM #10 — Blow-By
11. TM #11 — Connecting Rod Markings
12. TM #12 — Gears in a Typical Gear Train
13. TM #13 — Timing Marks on Gear Train
14. TM #14 — Engine Frames
15. TM #15 — Cylinder Liners
16. TM #16 — Cylinder Block and Cylinder Liner
17. TM #17 — Parts of the Crankshaft
18. TM #18 — Arrangement of Crankshaft Throws
19. TM #19 — Counterweights, Vibration Damper, and Flywheel
20. TM #20 — Crankshaft Lubrication
21. TM #21 — Bushings and Bearings
22. TM #22 — Bearing Locks
23. TM #23 — Bearing Oil Grooves

E. Job sheets

1. Job Sheet #1 — Remove, Inspect, and Install a Cylinder Head
2. Job Sheet #2 — Disassemble and Service a Valve Train
3. Job Sheet #3 — Service Valve Guides, Valve Seats, Valve Seat Inserts, and Assemble Valve Train
4. Job Sheet #4 — Service Piston and Install Piston Rings

SUGGESTED ACTIVITIES

5. Job Sheet #5 — Service Piston Pin and Connecting Rod
6. Job Sheet #6 — Install Precision-Insert Connecting-Rod Bearings
7. Job Sheet #7 — Remove, Service, and Install a Camshaft
8. Job Sheet #8 — Adjust Valve Clearance on a Valve-In-Head Engine
9. Job Sheet #9 — Inspect, Remove, and Replace a Cylinder Liner
10. Job Sheet #10 — Disassemble, Inspect, and Replace Crankshaft Assembly and Engine Bearings

F. Test

G. Answers to test

III. Unit reference — Foutes, William A. *Diesel Engine Mechanics.* Stillwater, Oklahoma: State Department of Vocational and Technical Education, Mid-America Vocational Curriculum Consortium, Inc., 1977.

CLEANING, INSPECTING, AND RECONDITIONING DIESEL ENGINES UNIT IV

INFORMATION SHEET

I. Terms and definitions

A. Backlash — Clearance between meshed gears

B. Bearing clearance — Measured difference between inside diameter of bearing and outside diameter of journal

C. Bearing crush — Height of bearing insert above bearing cap to allow for a fully seated bearing when tightened

D. Bed plate — Structure that supports main bearings

E. Blow-by — Combustion gases escaping to crankcase

F. Bridge or crosshead — Device that permits a single rocker arm to depress dual valves

G. Cam follower — Intermediate contact between camshaft and valve stem (Transparency #2)

(NOTE: A cam follower is also called a *valve lifter.*)

H. Center frame — Structure that carries cylinder liners

I. Crankpin — Outer end of crank throw

(NOTE: The crankpin is also called a *connecting rod journal.*)

J. Dual valves — Two valves operated by a single rocker arm

K. Dynamically balanced — Balanced against rotary outward force at high speed

L. Energy cell — Special removable combustion chamber for high-speed diesel engines (Transparency #4)

M. Frame — Stationary part that supports engine and keeps moving parts in line

N. Fuel injector — System that meters and sprays fuel into combustion chamber

O. Fuel injection nozzle — System that injects fuel under high pressure

P. Full-floating pin — Piston pin that moves in both rod and piston

INFORMATION SHEET

Q. Hydraulic valve lifters — Noiseless cam followers that automatically adjust for valve clearance

R. Incandescent — Glowing or burning

S. Integral cylinder — Cylinder and water jacket cast in one piece

T. Journal — That part of axle in contact with the bearing

U. Knurl — To roughen a piece of metal by pressing a series of crosshatched lines into the surface, thereby raising the area between these lines

V. Lugging — Overloading; causing unusual stress

W. Piston land — Area between ring grooves

X. Piston skirt — Outside part of piston below ring grooves

Y. Plastigauge — Soft, oil-soluble plastic thread

Z. Poppet valve — Disc with stem that rises perpendicularly to or from its seat and is opened by a cam and closed by a spring

AA. Rocker arm — Lever that transmits action of cam to valve stems

BB. Rocker arm assembly — Shaft, rocker arm, and cam follower

CC. Rocker arm shaft — Device that serves as a fulcrum for rocker arms (Transparency #2)

DD. Service — To clean, inspect, lubricate, or adjust

EE. Short block — Engine block without cylinder head and external accessories

FF. Statically balanced — Balanced while at rest

GG. Torque — Twisting effort

HH. Turbulence — High-velocity swirling of air within the combustion chamber

II. Valve clearance — Definite space between rocker arm and valve stem (Transparency #6)

JJ. Valve guide — Opening or bore through which valve stem passes (Transparency #1)

(NOTE: Some guides are pressed into place; others are drilled into head metal.)

INFORMATION SHEET

KK. Valve seat — That portion in head upon which valve face rests to close the port (Transparency #1)

LL. Valve seat angle — Angle between the seat surface and cylinder head surface, either 30 or 45 degrees

MM. Valve spring — Helical spring used to close the valve (Transparency #1)

NN. Valve spring retainer — Device that holds valve spring on the valve stem

OO. Vibration damper — Member that reduces torsional stress on the crankshaft

II. Major parts of a cylinder head assembly (Transparency #5)

A. Intake ports

B. Exhaust valves

C. Valve seat

D. Valve guide

E. Fuel injector or nozzle

F. Fuel injector tubes

G. Rocker arm

H. Pushrod

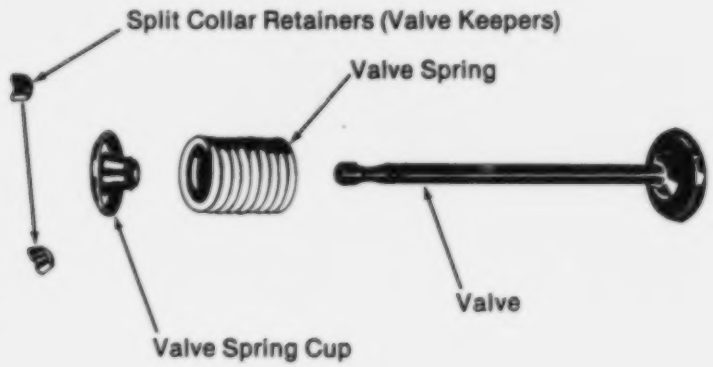
I. Cam followers

J. Camshaft

INFORMATION SHEET

III. Primary parts of a valve assembly (Figure 1)

FIGURE 1



IV. Types of valve rotators (Transparency #7)

A. Release type

B. Positive type

V. Valve arrangement and engine head types (Transparency #8)

A. I-Head — Both valves above cylinder

B. H-Head — Both valves at an angle above cylinder (V-block)

C. F-Head — One valve above and one to side of cylinder

D. L-Head — Both valves to side of cylinder

VI. Locations of turbulence chambers (Transparency #8)

A. Chamber in cylinder head

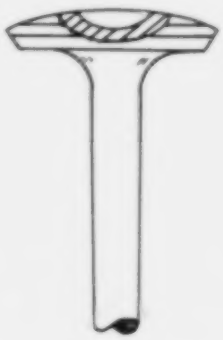
B. Chamber in piston

INFORMATION SHEET

VII. Types of engine valves (Figures 2-4)

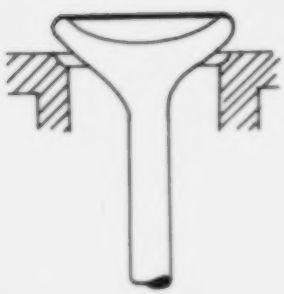
A. Standard

FIGURE 2



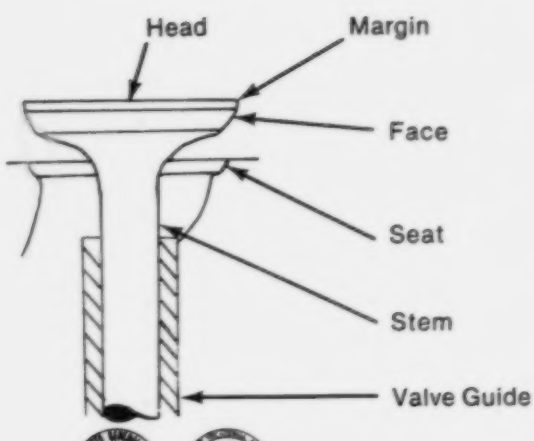
B. Tulip

FIGURE 3



C. Flattop

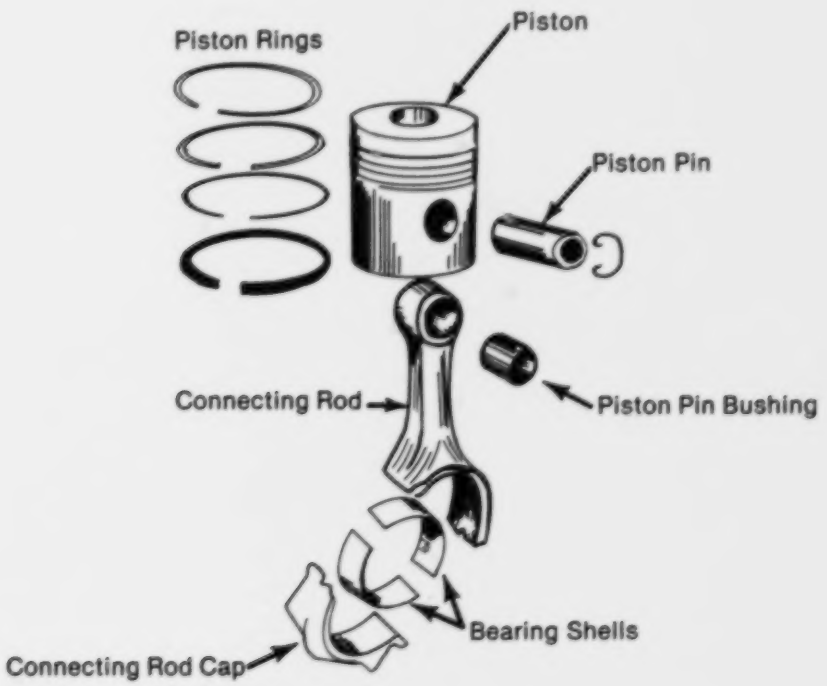
FIGURE 4



INFORMATION SHEET

VIII. Primary parts of piston and connecting rod assembly (Figure 5)

FIGURE 5



IX. Functions of the piston

A. Receiving force of combustion

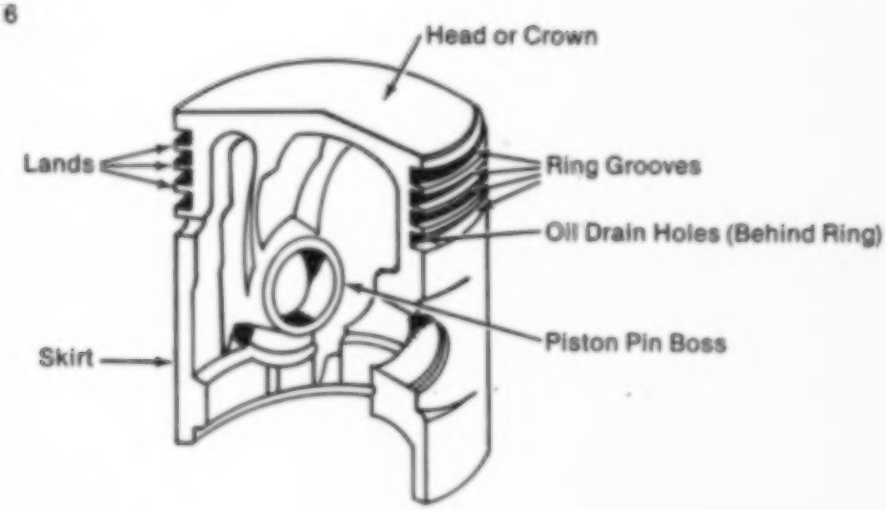
B. Transmitting this force to crankshaft

C. Carrying piston rings, which seal and wipe cylinder

INFORMATION SHEET

X. Main parts of a piston (Figure 6)

FIGURE 6



XI. Functions of piston rings

A. Form a gas-tight seal between piston and cylinder

B. Help cool piston by transferring heat

C. Control lubrication between piston and cylinder wall

XII. Types of piston rings (Transparency #9)

A. Compression rings

B. Oil control rings

XIII. Possible causes of high oil consumption and blow-by (Transparency #10)

A. Piston rings installed incorrectly

B. Stuck oil ring

C. Plugged oil ring

D. Top ring broken or top groove worn

E. Overall wear in piston, rings, or cylinder

F. Physical damage to pistons

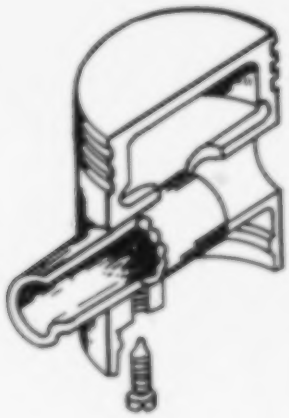
INFORMATION SHEET

XIV. Types of piston pins (Figures 7-9)

A. Fixed

(NOTE: Fixed pin moves in rod and is fastened to piston.)

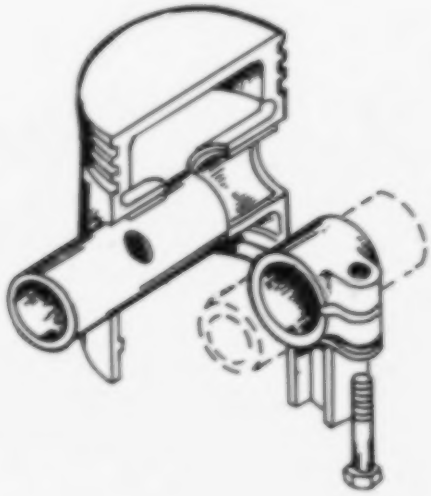
FIGURE 7



B. Semifloating

(NOTE: Semifloating pin moves in piston and is fastened to rod.)

FIGURE 8

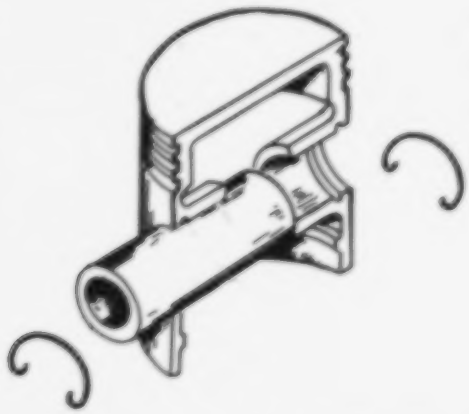


INFORMATION SHEET

C. Full-floating

(NOTE: FUll-floating pin moves in both piston and rod and is fastened by spring clips.)

FIGURE 9



XV. Reason for marking on connecting rod, piston, and bearing cap (Transparency #11) — To allow for reinstallation in original location and position

XVI. Parts actuated by the camshaft on some diesel engines

A. Intake valve

B. Exhaust valve

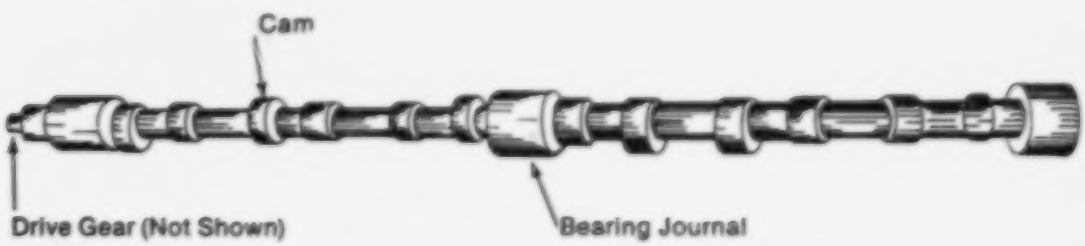
C. Unit injector

D. Air starting valves

XVII. Primary parts of a camshaft (Figures 10 and 11)

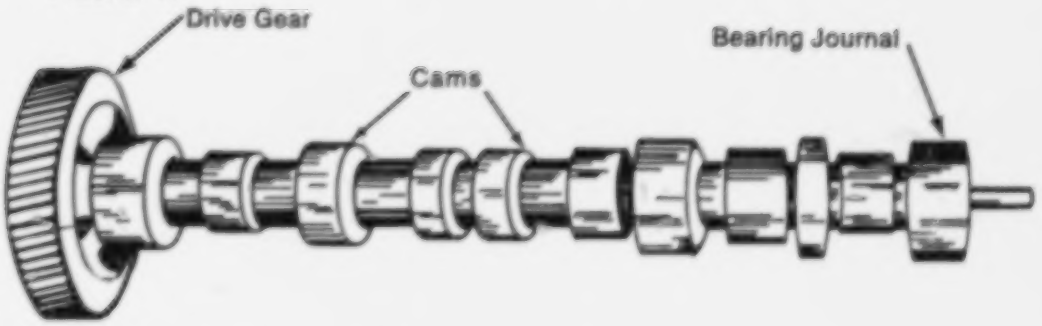
EXAMPLE:

FIGURE 10



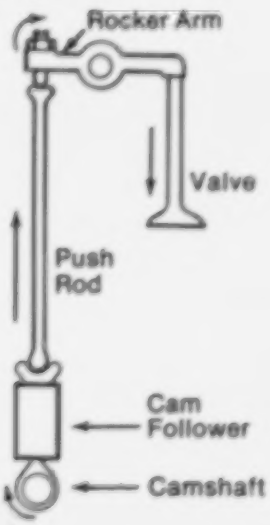
INFORMATION SHEET

FIGURE 11



XVIII. Parts in a valve train (Figure 12)

FIGURE 12



XIX. Valve timing on a four-cycle engine — Camshaft turns at one-half the speed of crankshaft, and each valve is opened and closed once during two revolutions of crankshaft

XX. Gears found in a typical gear train (Transparency #12)

A. Camshaft gear

B. Crankshaft gear

C. Idler gear

D. Fuel injection pump and governor drive gear

(NOTE: The idler gear — gear placed between a driving and a driven gear to make them rotate in the same direction — does not affect gear ratio.)

INFORMATION SHEET

XXI. Gears that are marked in the gear train to ensure correct valve timing (Transparency #13)

- A. Crankshaft gear
- B. Idler gear
- C. Camshaft gear

XXII. Purpose of through bolts on an A-frame engine (Transparency #14) — Bed plate supports frames, frames support cylinder block, cylinder block supports cylinder head, and through bolts tie them all together

XXIII. Ways cylinder blocks may be constructed (Transparencies #15 and #16)

- A. Cylinder bore an integral part of block
- B. Cylinder bore with removable wet liner
- C. Cylinder bore with removable dry liner

XXIV. Advantages of a removable cylinder liner

- A. Allows room for lengthwise expansion
- B. May be replaced separately when worn

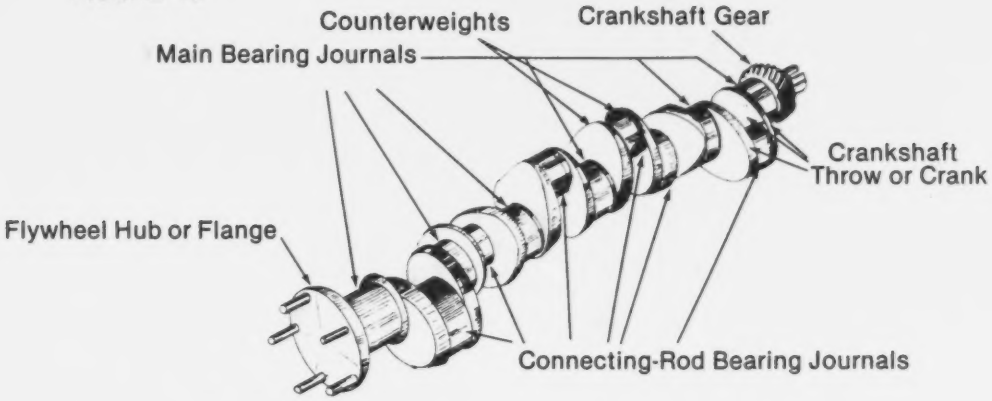
XXV. Advantages of wet and dry liners (Transparency #15)

- A. Wet liner
  1. Provides better cooling of cylinder than dry liner
  2. May be replaced separately when worn
- B. Dry liner
  1. Easier to replace than wet liner
  2. Less expensive than wet liner
  3. Allows room for lengthwise expansion
  4. May be replaced separately when worn

INFORMATION SHEET

XXVI. Parts of a crankshaft (Figure 13; Transparency #17)

FIGURE 13



XXVII. Factors that influence crankshaft design

A. Engine balance

B. Smoothness of turning shaft

C. Equalization of loads on main bearings

D. Firing order of engine

XXVIII. Arrangement of crankshaft throws (Transparency #18)

A. Two-cylinder and four-cylinder engines — Throws 180 degrees apart

B. Three-cylinder and six-cylinder engines — Throws 120 degrees apart

C. Eight-cylinder engine — Throws 90 degrees apart

XXIX. Ways crankshaft balance is maintained (Transparency #19)

A. Counterweights

B. Vibration damper

C. Flywheel

XXX. How crankshaft and surrounding parts are lubricated (Transparency #20)

A. Oil pressure through holes in journal

B. Oil spray from excess

INFORMATION SHEET

XXXI. Bushings and bearings (Transparency #21)

A. Bushing — Round sleeve used to support light loads and slow speeds

B. Bearing — Half-round sleeve used to support heavy loads and high speeds

XXXII. Types of bearing locks (Transparency #22)

A. Lip slot

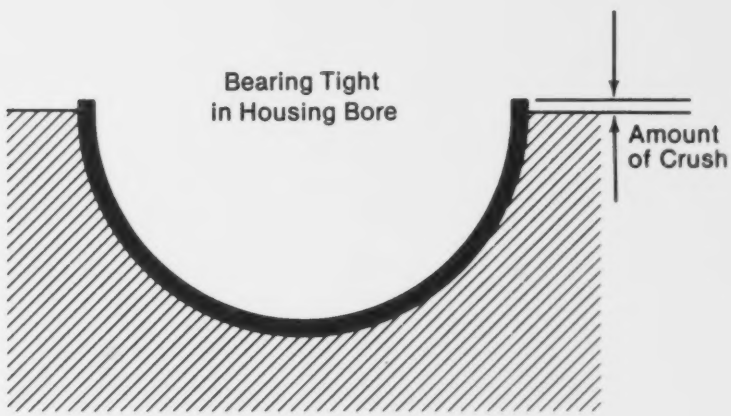
B. Dowel

XXXIII. Bearing crush and bearing spread

A. Bearing crush (Figure 14)

(NOTE: Bearing crush holds the bearing in place and keeps the bearing from turning when the engine runs. Crush must exert a force of at least 12,000 psi stress between the bearing and the housing bore to hold it in place.)

FIGURE 14



INFORMATION SHEET

B. Bearing spread (Figure 15)

(NOTE: Bearing spread is from 0.005 to 0.070 inch wider than the housing bore. This spread helps to hold the bearing in place during installation.)

FIGURE 15

XXXIV. Purpose of bearing oil grooves — To carry oil to the connecting rod (Transparency #23)

XXXV. Engine indications of bearing failure

A. Drop in lubricating oil pressure

B. Excessive oil consumption

C. Engine noise sounding like rhythmic knock

XXXVI. Functions of the flywheel

A. Storing energy for momentum between power strokes

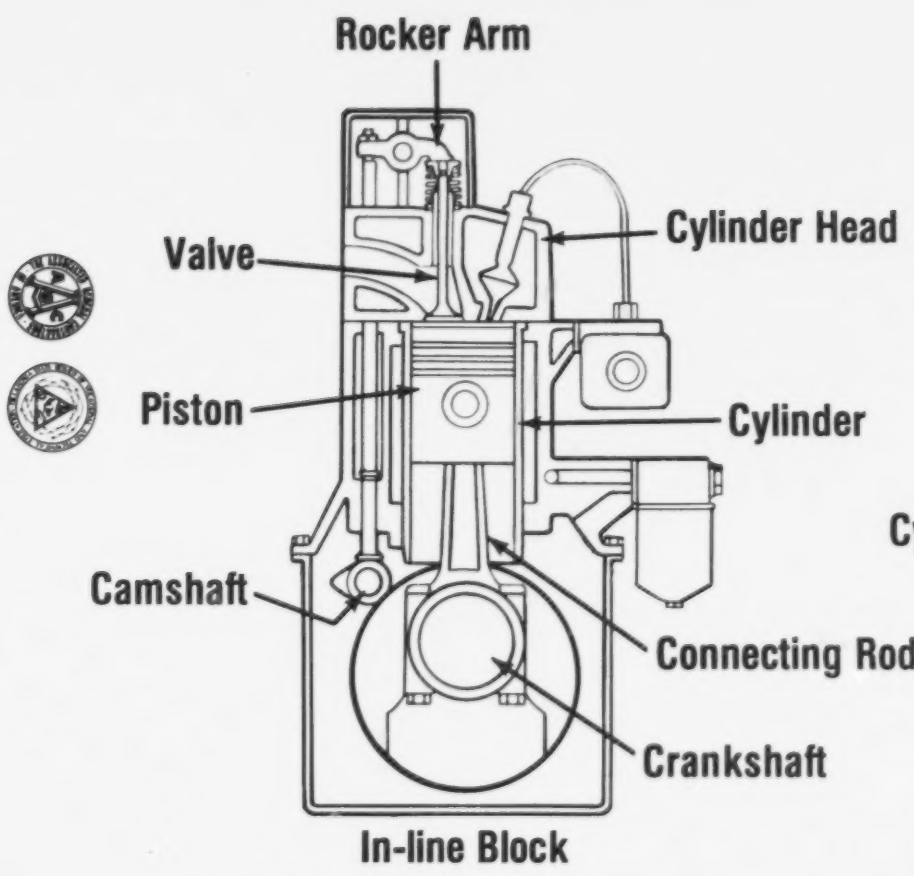
B. Smoothing speed of crankshaft

C. Transmitting power to driven machine

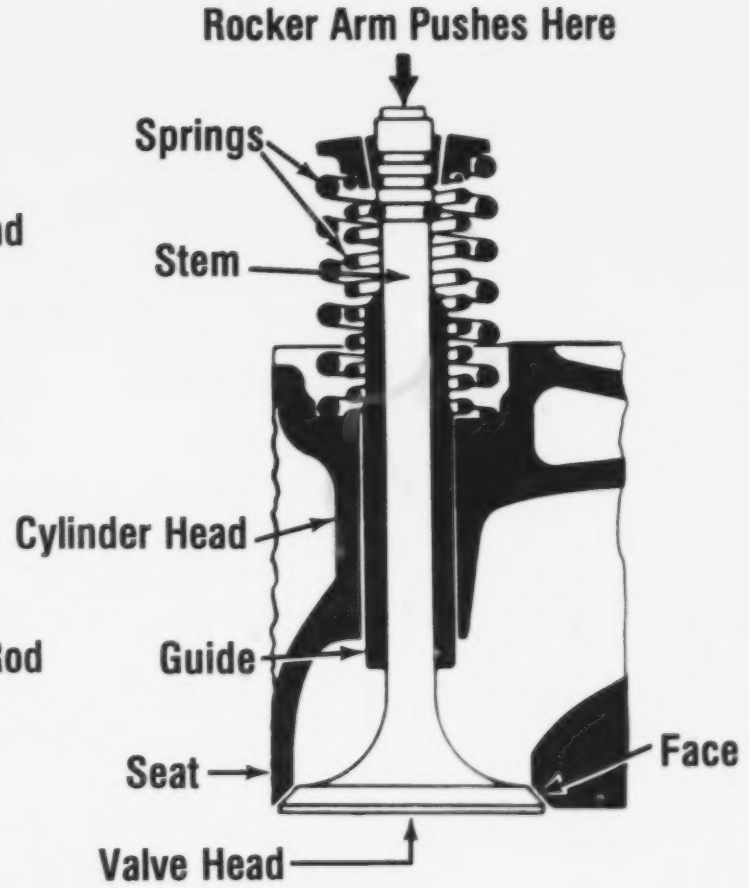
D. Providing a drive for starter via ring gear

E. Serving as a facing for engine clutch

Valve Assembly



620



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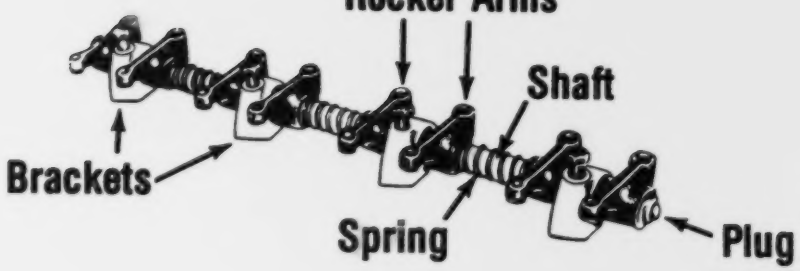
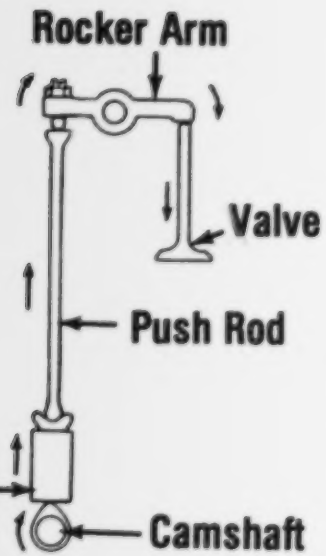
TM #1

HEM - 339-B

Valve Rocker Arm Assembly





622

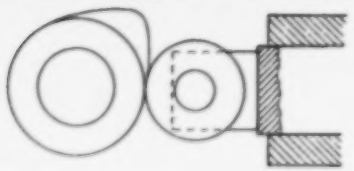
623

TM #2

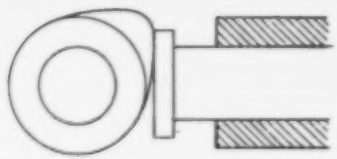
HEM - 341-B

Cam Followers

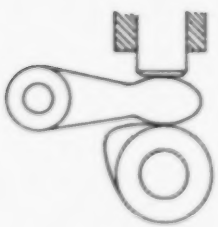
Roller-Type Follower



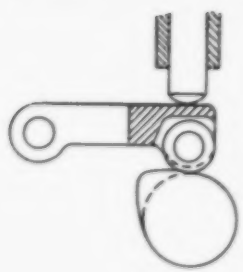
Flat or Mushroom Follower



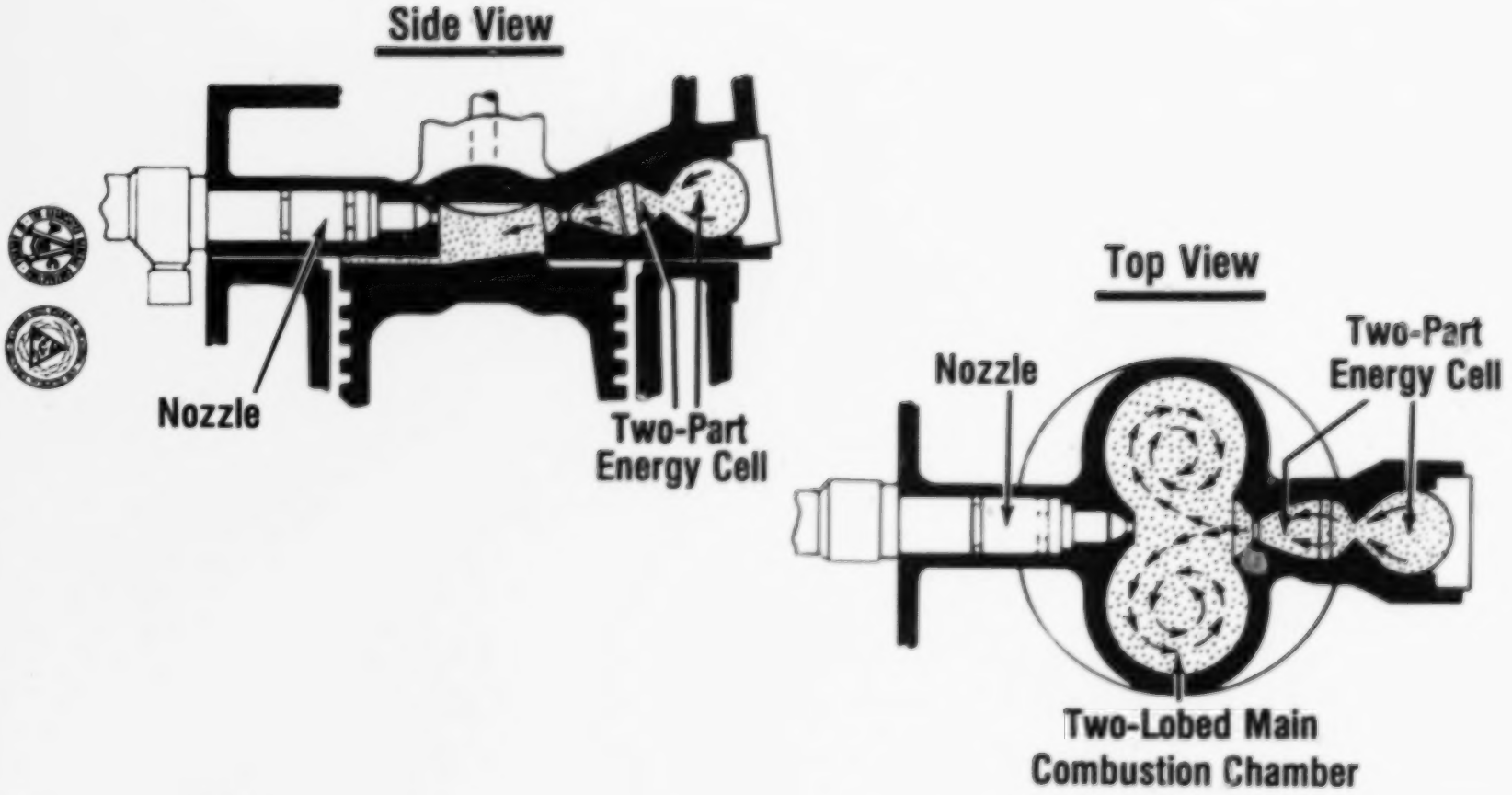
Pivoted Follower



Pivoted Pin Follower with Roller



Energy Cell



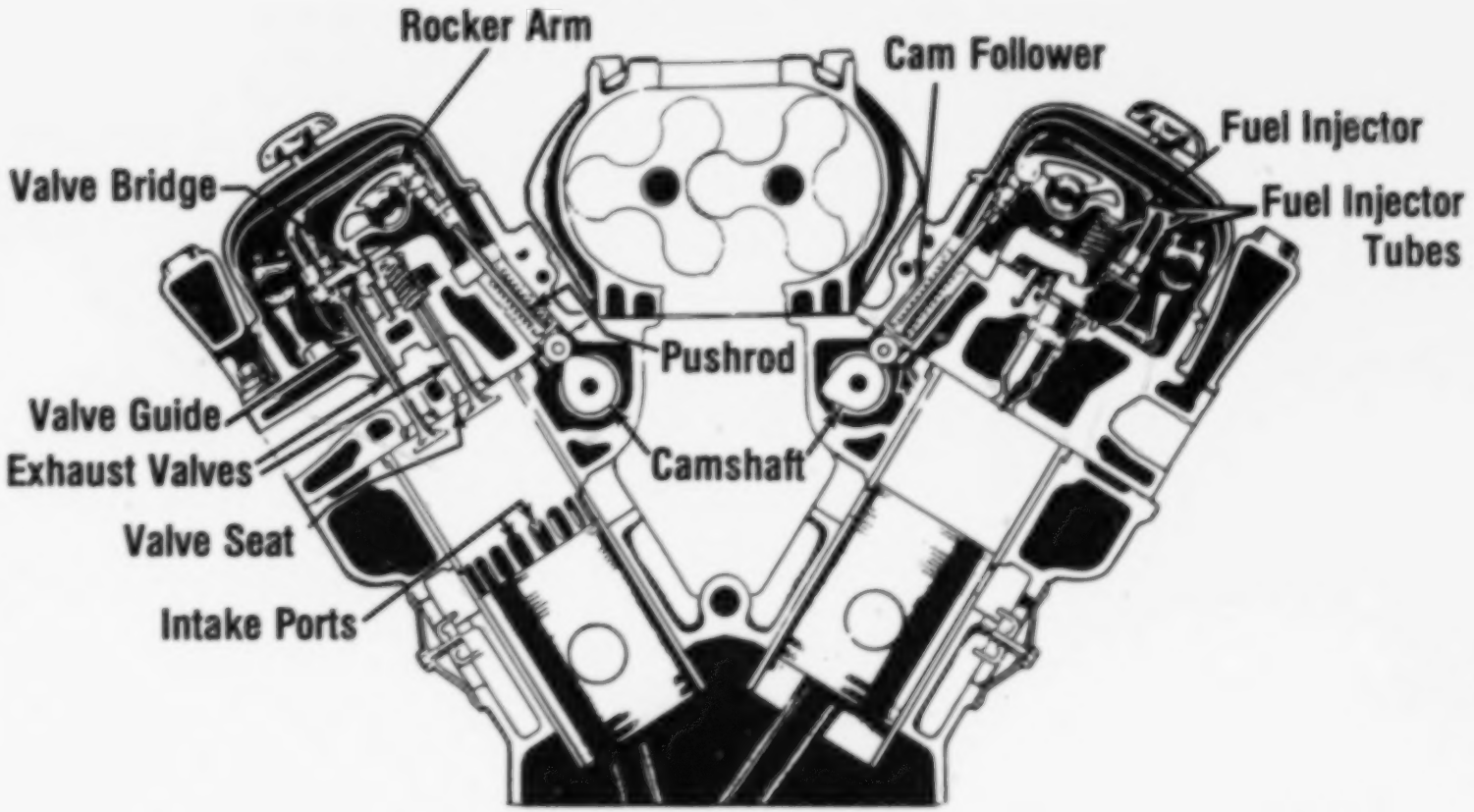
TM #4

626

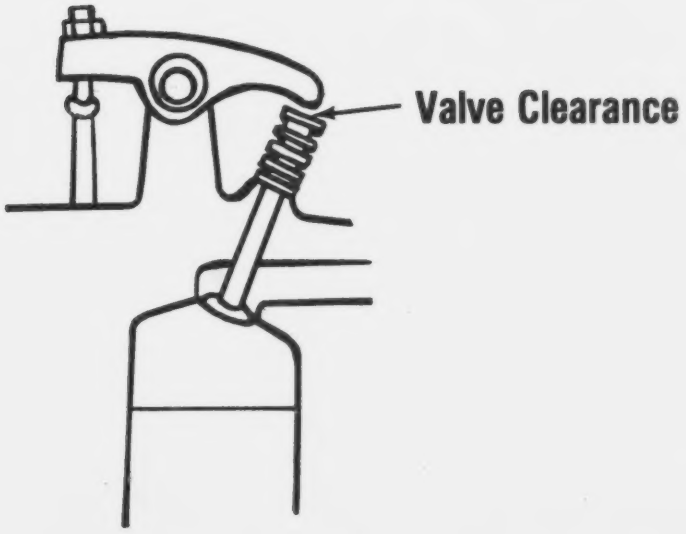
627

HEM - 345-B

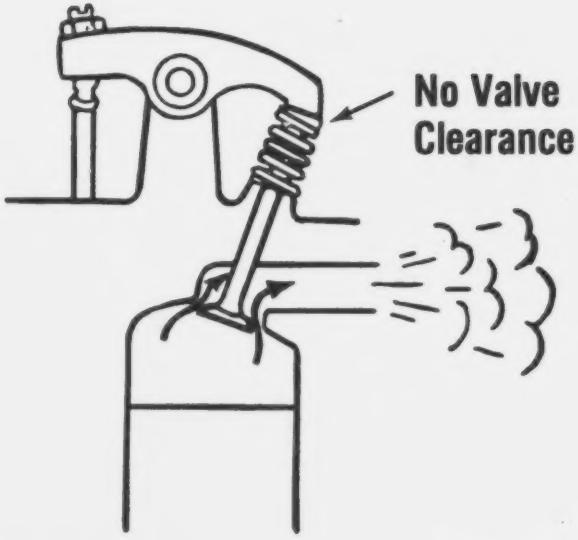
Valve and Fuel Injector (Two-Cycle Engine)



Valve Clearance



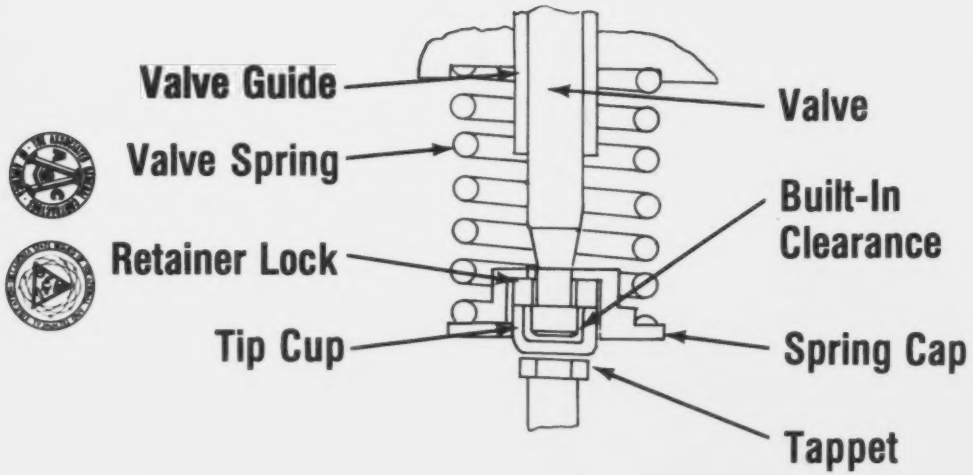
Valve Closes and Seals
Gases in Cylinder



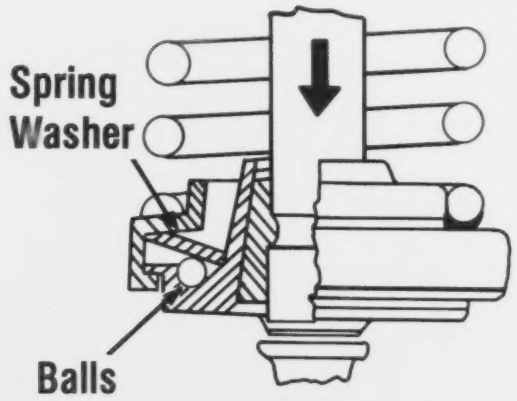
Valve Does Not Seat.
Power is Lost and Valve
Overheats.

Problem of Too Little Valve Clearance

Valve Rotators



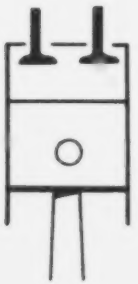
Release-Type



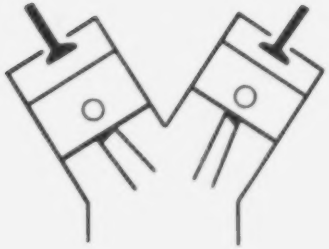
Positive-Type

Valve Arrangments and Turbulence Chambers

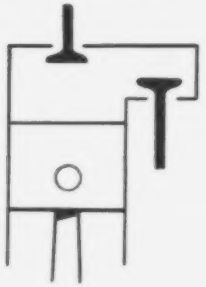
I-Head



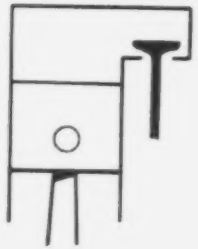
H-Head



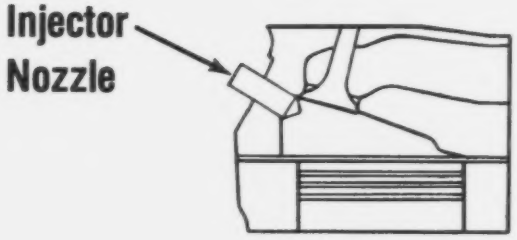
F-Head



L-Head



Turbulence Chamber
in Cylinder Head



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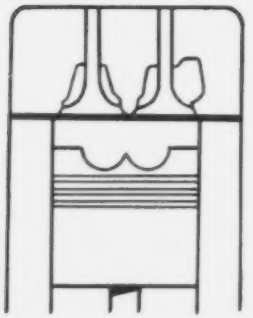
Turbulence Chamber
in Top of Piston



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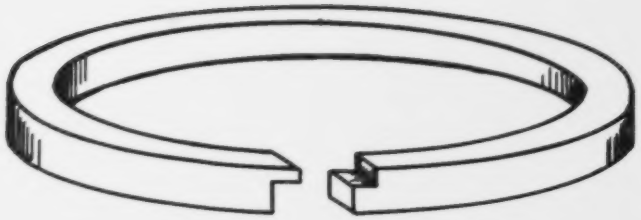
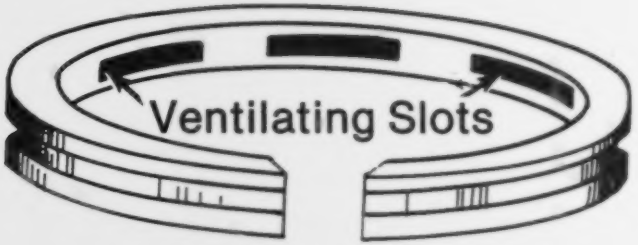
TM #8

HEM - 353-B

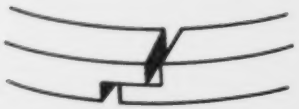
Piston Rings



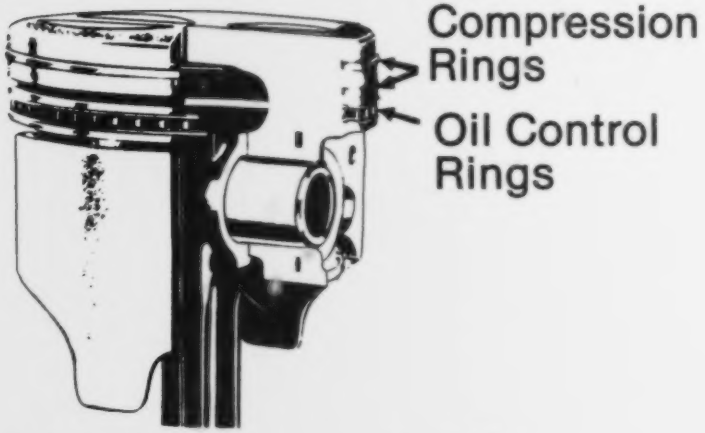
Compression Ring



Double-Land Beveled and Ventilated Oil Ring

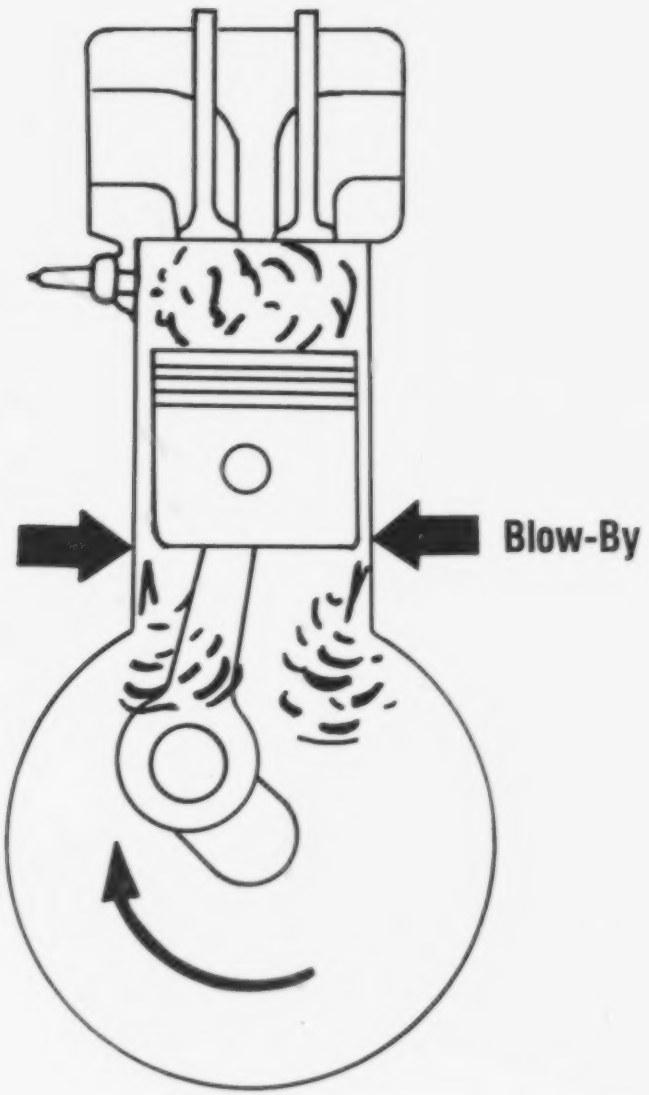


Compression Rings with Simple Joints



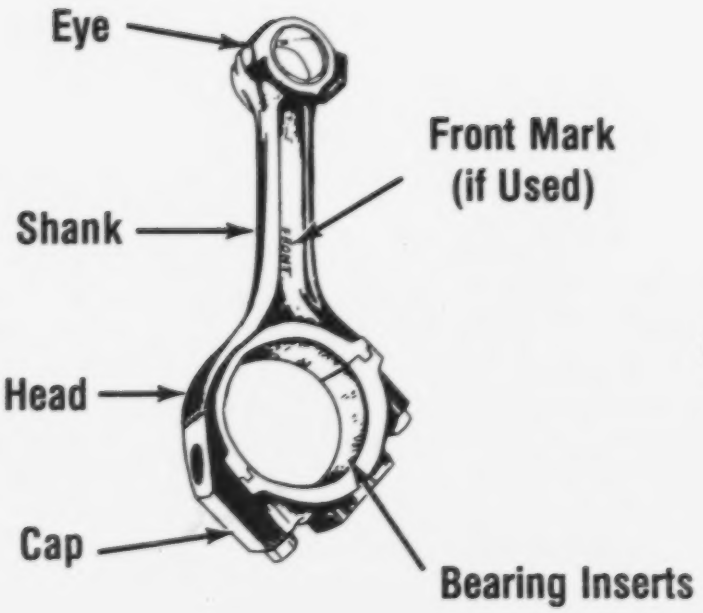
Piston Rings for a Typical Piston

Blow-By

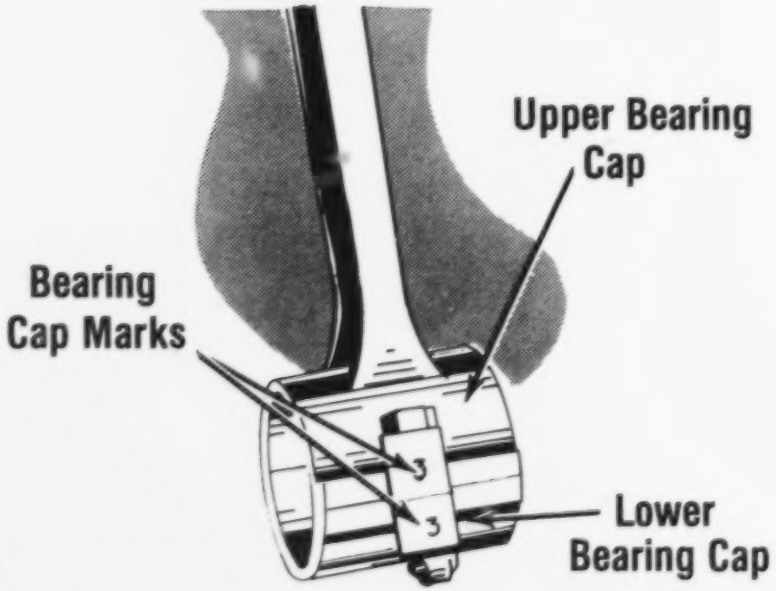


Blow-By of Gases in Cylinder

Connecting Rod Markings



Connecting Rod Angle Cut



Connecting Rod Square Cut

TM #11

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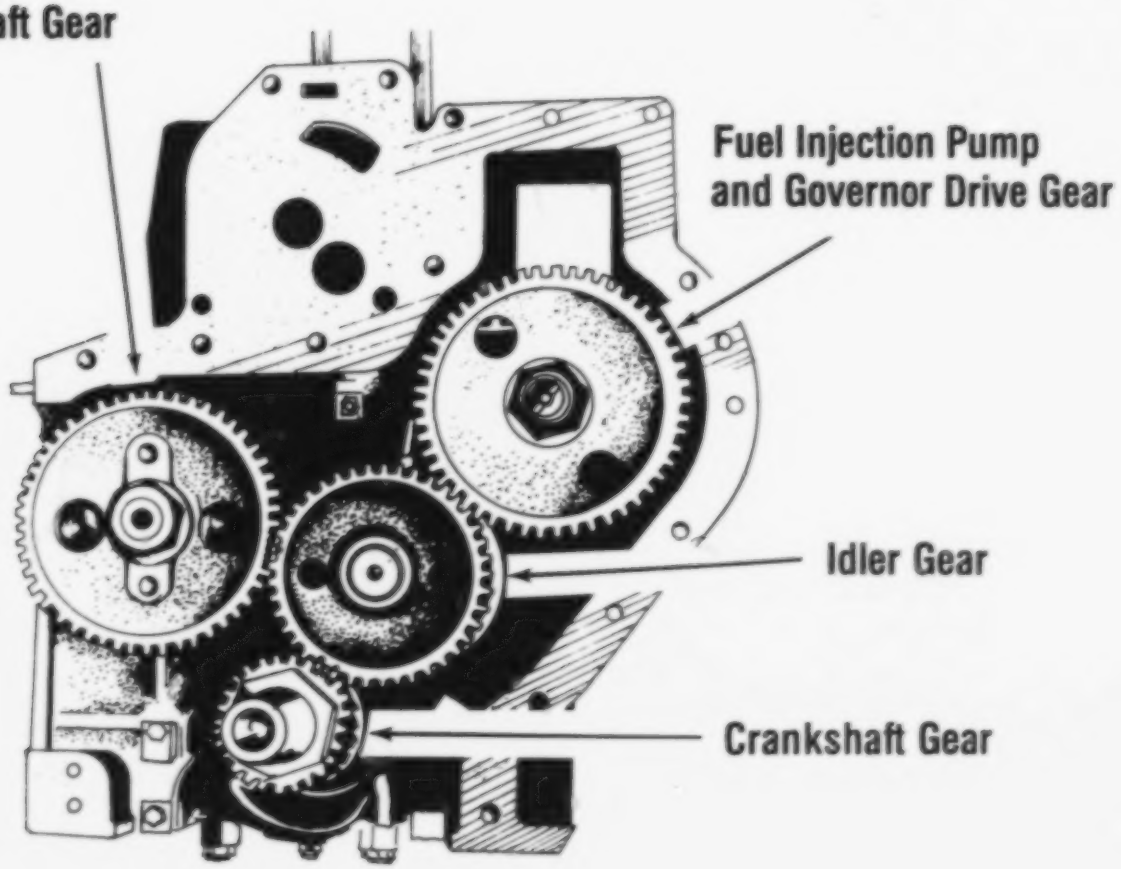
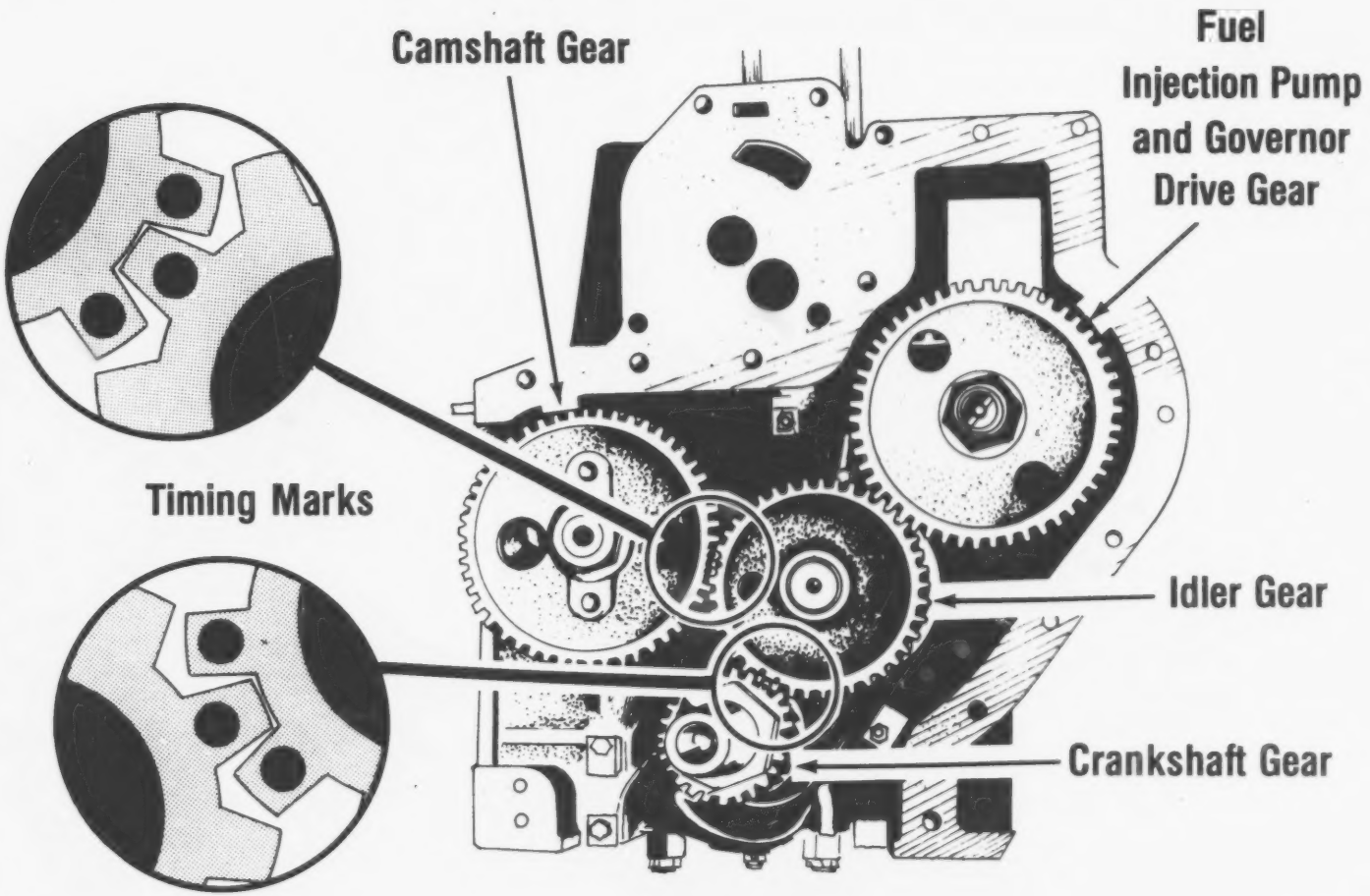
HEM - 359-B

Gears in a Typical Gear Train



Timing
Gears

Timing Marks on Gear Train



TM #13

643

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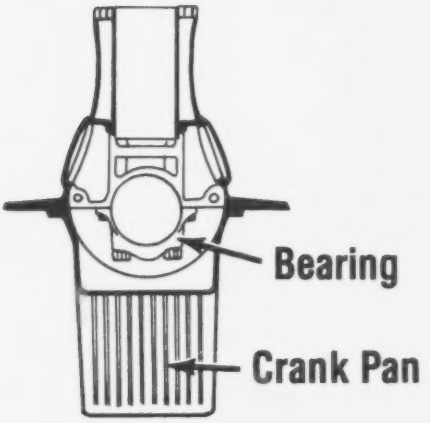
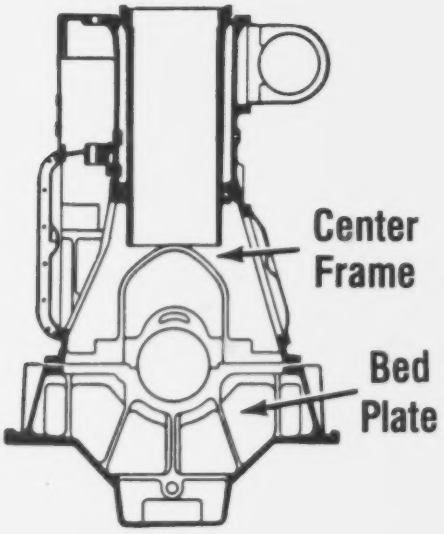
HEM - 363-B

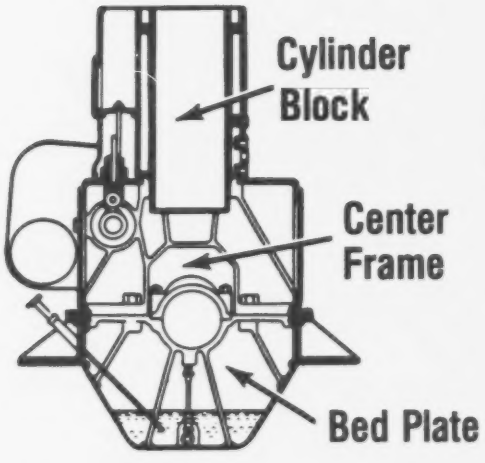
Engine Frames



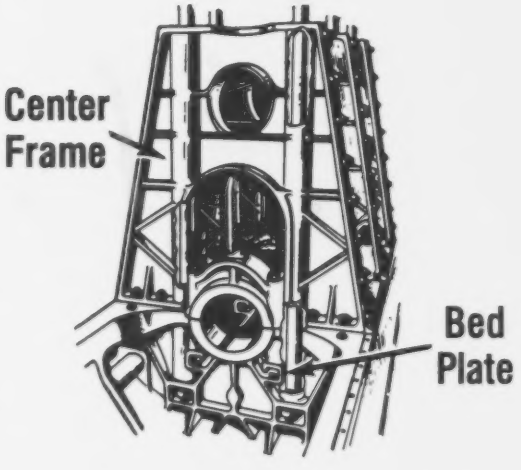
Automotive-Type Frame



Two-Piece Frame

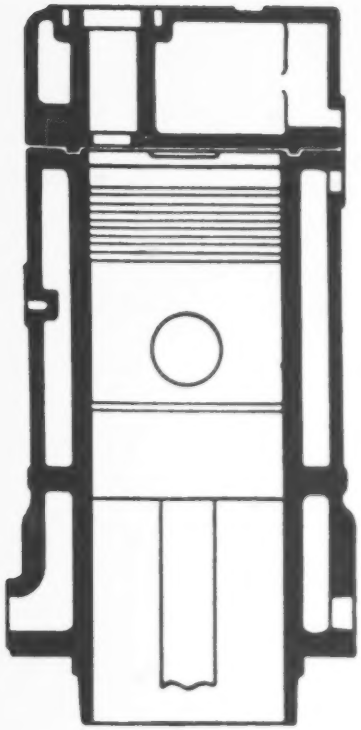


Three-Piece Frame



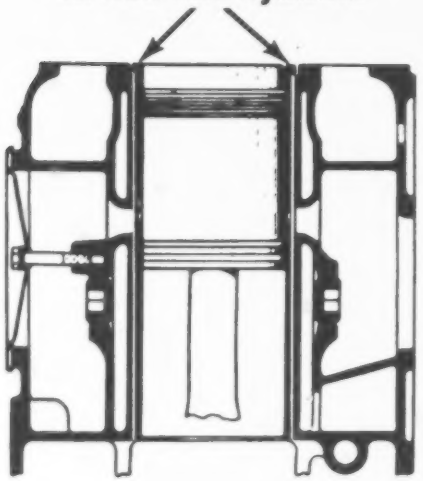
A-Frame Construction

Cylinder Liners



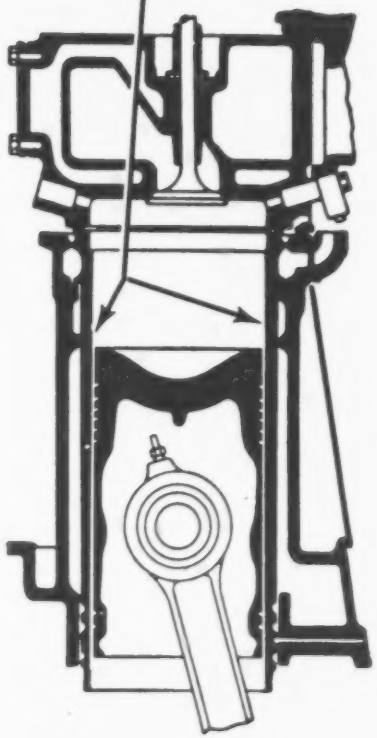
Cylinder Cast as One Piece

Liner is a Sleeve
Inside the Cylinder



Dry Cylinder Liner

Liner Forms
the Cylinder Itself



Wet Cylinder Liner

TM #15

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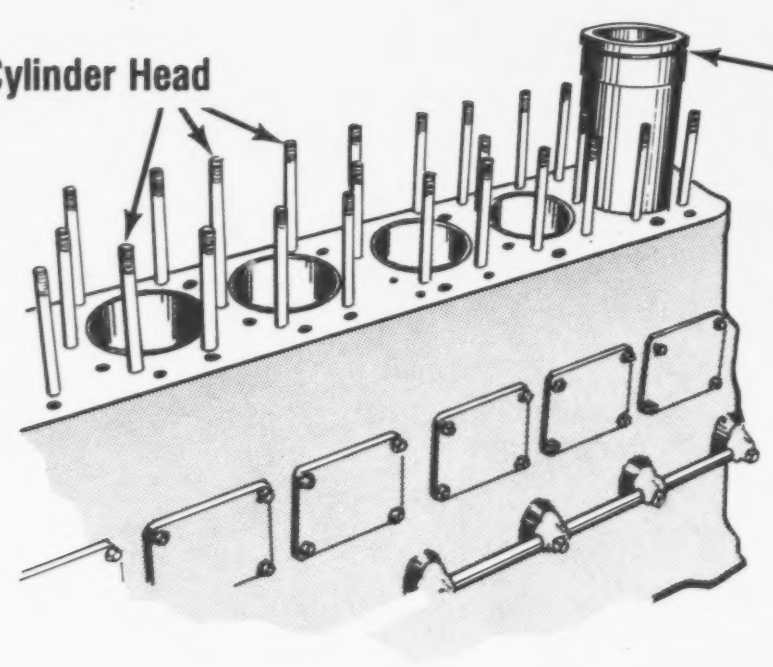
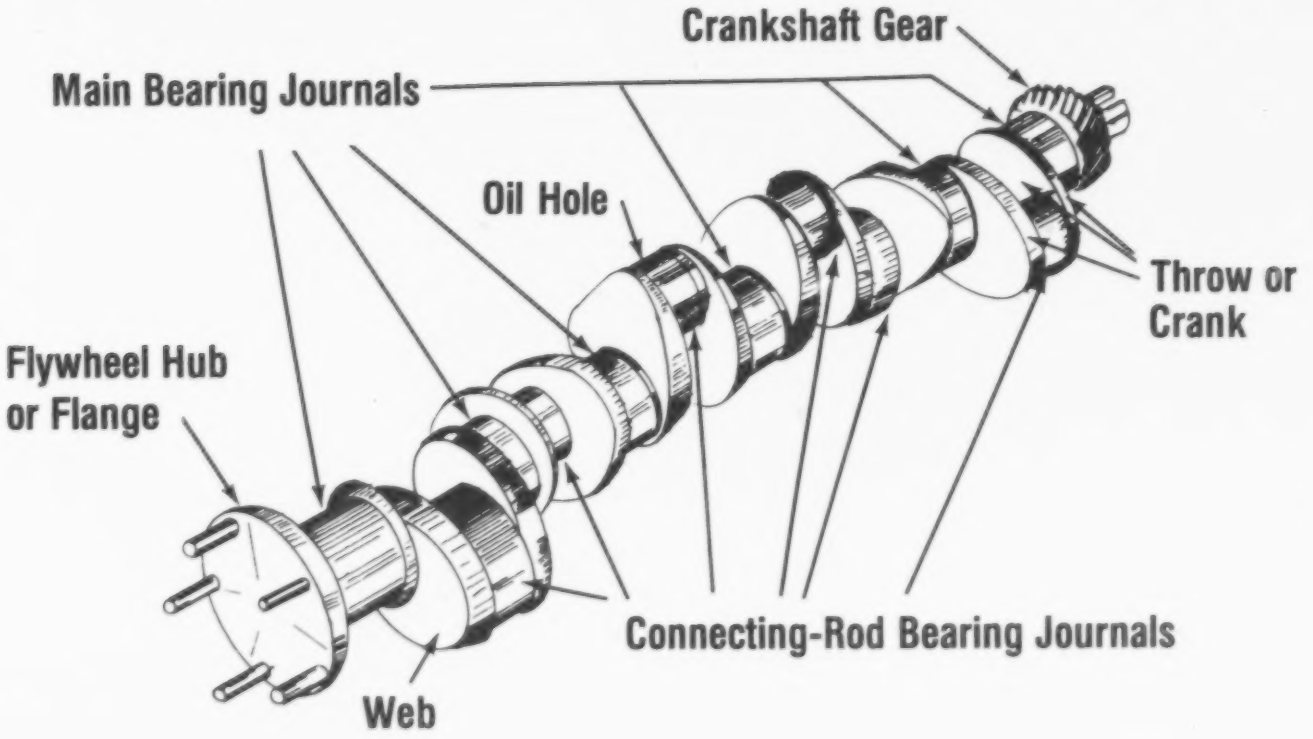
HEM - 367-B

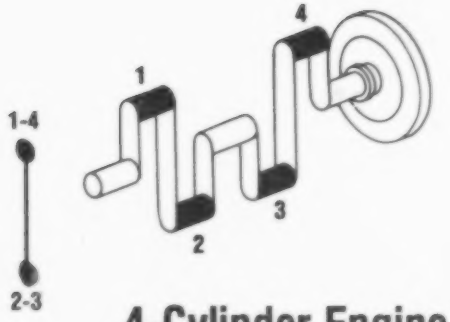
Cylinder Block and Cylinder Liner



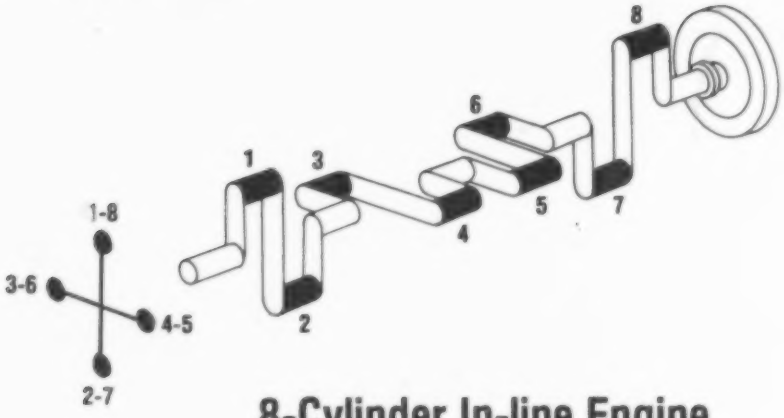
Parts of the Crankshaft



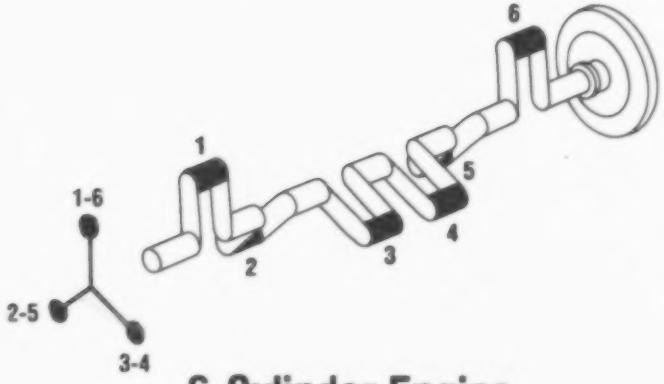
Arrangement of Crankshaft Throws



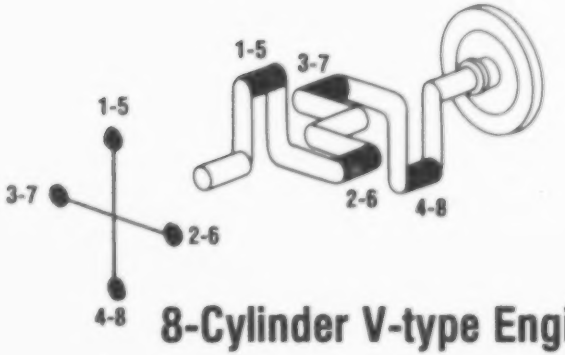
4-Cylinder Engine



8-Cylinder In-line Engine



6-Cylinder Engine



8-Cylinder V-type Engine

TM #18

652

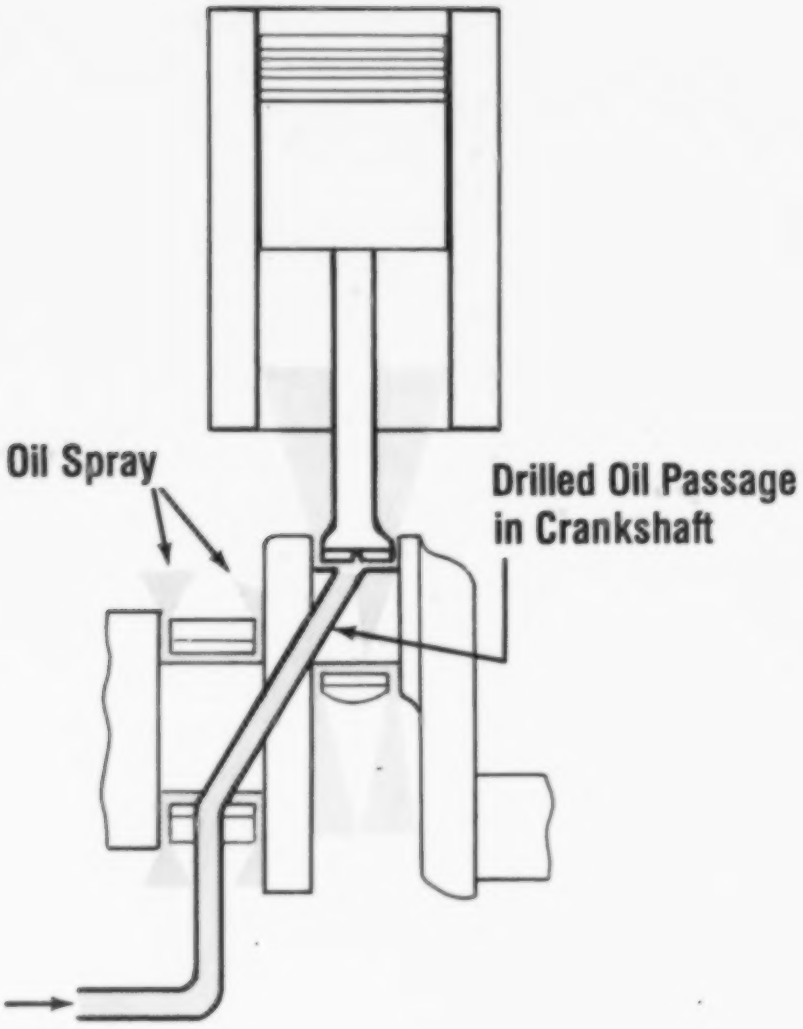
653

HEM - 373-B

Counterweights, Vibration Damper, and Flywheel

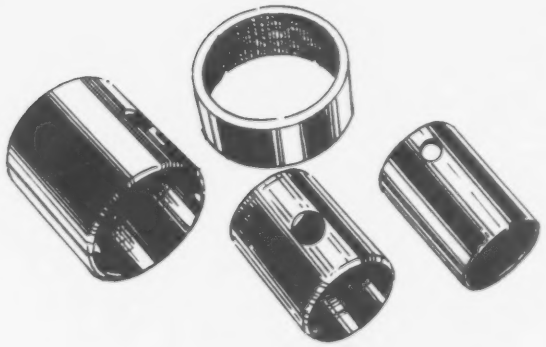
A Six-Cylinder, Seven-Main-Bearing Crankshaft

Crankshaft Lubrication



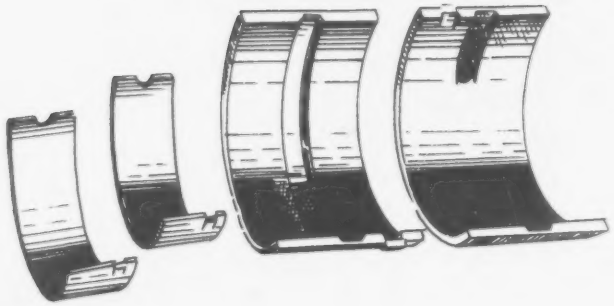
Bushings and Bearings

Bushings



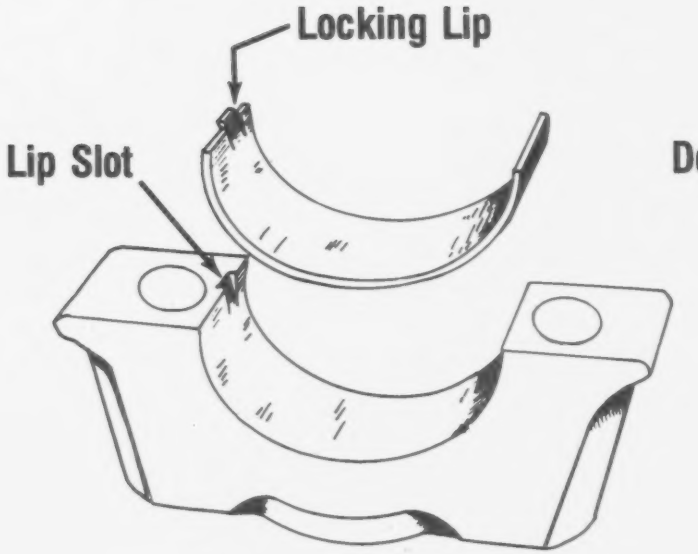
For Light Loads

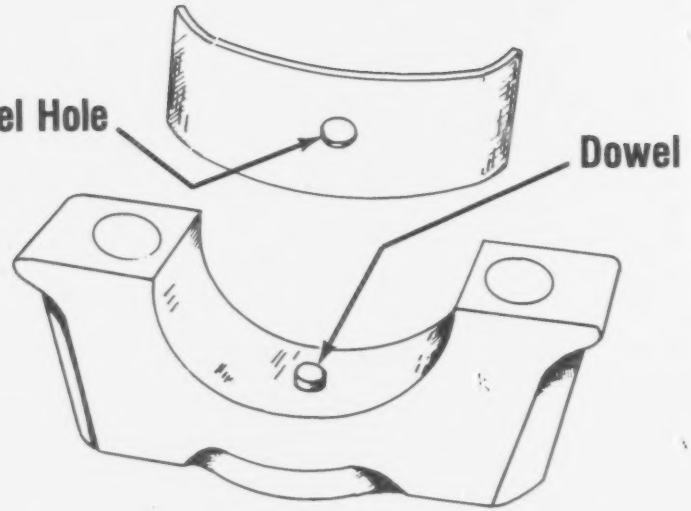
Bearings



For Heavy Loads

Bearing Locks





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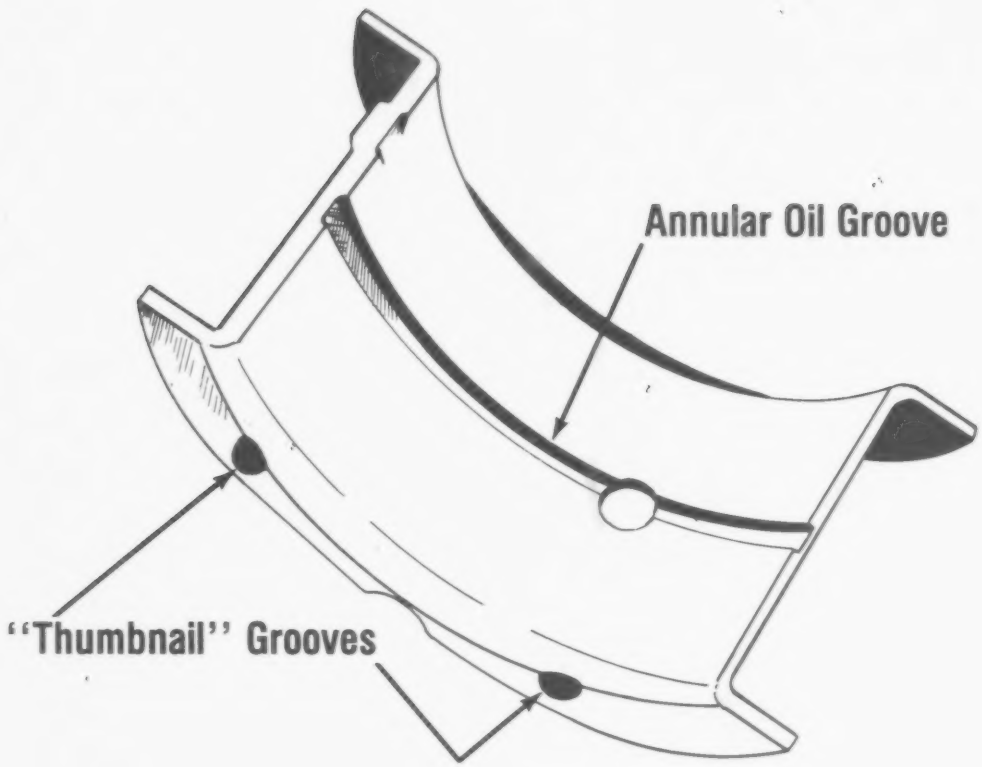
660

TM #22

HEM - 381-B

Bearing Oil Grooves



CLEANING, INSPECTING, AND RECONDITIONING DIESEL ENGINES UNIT IV

JOB SHEET #1 — REMOVE, INSPECT, AND INSTALL A CYLINDER HEAD

I. Equipment and materials

- A. Steam supply
- B. Air compressor
- C. Chain hoist of sufficient capacity
- D. Brass hammer
- E. Torque wrench
- F. Straightedge
- G. Feeler gauge
- H. Head gasket scraper
- I. Wire brush
- J. Basic hand-tool set
- K. New head gasket
- L. Shop towels
- M. Eye protection
- N. Appropriate service manual

II. Procedure

- A. Remove cylinder head
  1. Check for oil, water, fuel, or compression leaks around cylinder head
  2. Steam clean engine
  3. Drain coolant from engine
  4. Remove accessories attached to cylinder head, allowing a clear place to work
  5. Remove rocker arm cover and rocker arm assembly, if used

6. Remove cylinder head studs as suggested by manufacturer's specifications

7. Attach suitable lifting device to head (Figure 16)

FIGURE 16

8. Break head loose, using suitable pry bar and location

   (CAUTION: Do not pry on the contact surfaces.)

9. Place cylinder head in head-holding fixture or equivalent, and reinstall accessories

B. Inspect cylinder head

1. Clean cylinder head and contact surfaces

2. Clean mating surfaces of block and head thoroughly

3. Check for damage to the sealing surfaces of head or block

4. Check liner protrusion for proper specification

5. Clean all carbon deposits from the head by scraping or brushing with a wire brush

6. Check for lime deposits in water passages and remove soft plug, if used

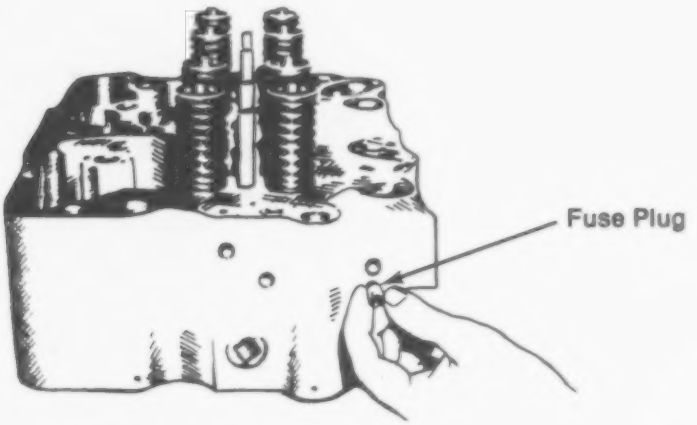
   (NOTE: Use a recommended solution and dip the head to clean out scale and lime.)

JOB SHEET #1

7. Examine fuse plug for signs of overheating (Figure 17)

   (NOTE: Fuse plugs contain a metal alloy center that melts if engine is overheated.)

FIGURE 17



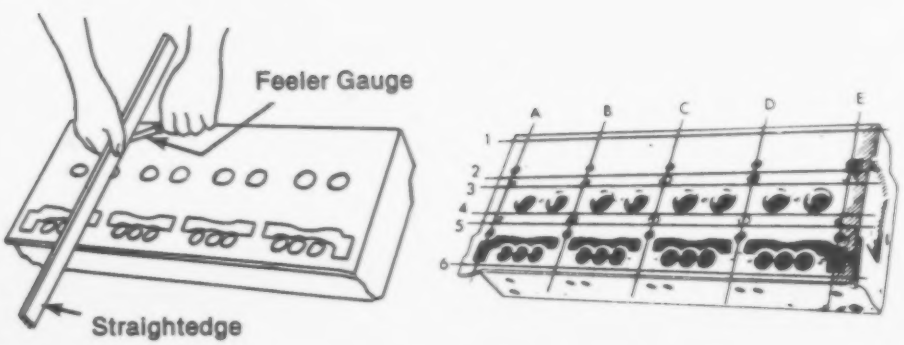
8. Inspect and replace soft plug as needed
9. Install new plug if metal alloy has melted

   (NOTE: If fuse plug has melted, check carefully for further damage.)

10. Use a heavy straightedge and feeler gauge to check for warpage at each end and between all cylinders

    (NOTE: Also check for end-to-end warpage in at least six places. See Figure 18.)

FIGURE 18



JOB SHEET #1

11. Decide whether to reinstall or reface head

    (NOTE: Consult the engine technical manual for refacing limits.)

12. Check head for leaks or cracks

    a. Water and air pressure method

        1) Seal the head and connect to an air hose

        2) Immerse in hot water (180°F to 200°F) for 15 minutes

        3) Watch for any air bubbles that appear in water, indicating leaks

    b. Magnetic crack detector method (Figure 19)

        1) Place magnetic crack detector over suspected area, setting up a magnetic field

        2) Sprinkle fine, white metallic powder over area

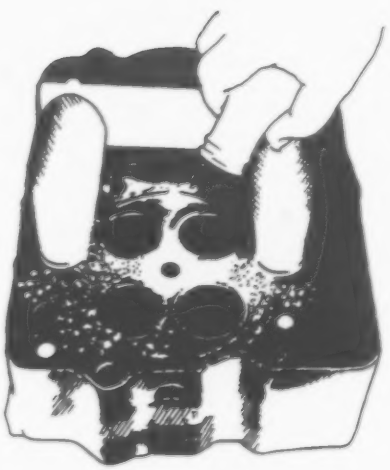
        3) Rotate tool 90 degrees

        4) Blow off excess powder

        5) Inspect for cracks

            (NOTE: Any cracks will show clearly in white.)

FIGURE 19



JOB SHEET #1

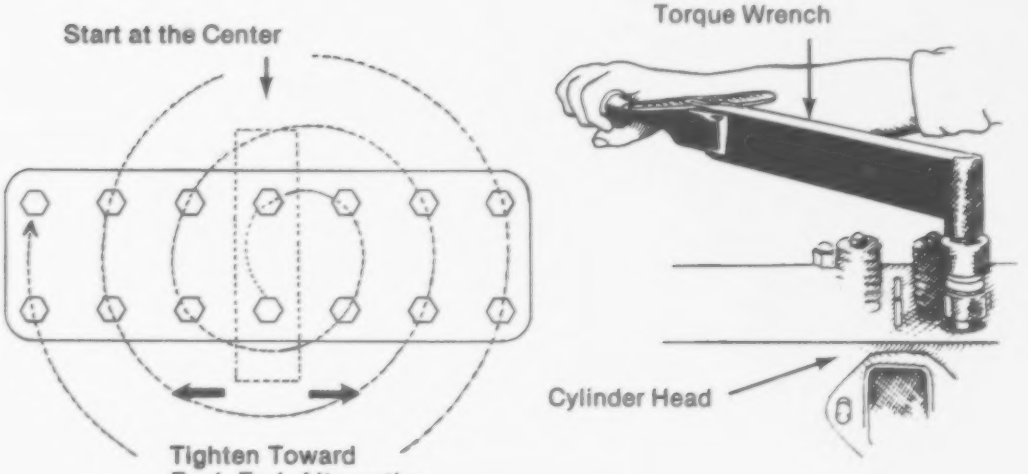
C. Install cylinder head

1. Inspect cylinder head and contact surfaces
2. Inspect for scratches or nicks on sealing surfaces of head and block
3. Inspect and clean cylinder-head cap screws and threads
4. Install new cylinder head gasket

   (NOTE: Follow engine manufacturer's recommendation for applying a sealing compound to one or both sides of the head gasket. Check to be sure that water passage holes are aligned with holes in block. Use aligning dowels if required.)

5. Set head squarely on block without disturbing the head gasket
6. Clean and lightly oil bolts or studs
7. Start stud nuts or cap screws; finger tighten
8. Snug down in correct sequence according to manufacturer's manual from center of head out (Figure 20)

FIGURE 20



9. Tighten each nut

   (NOTE: Refer to engine manual for torquing procedures. After the engine has been running a few hours, retighten the stud nuts in the correct sequence with the torque wrench.)

D. Clean work area; clean and put away all tools and equipment

CLEANING, INSPECTING, AND RECONDITIONING DIESEL ENGINES UNIT IV

JOB SHEET #2 — DISASSEMBLE AND SERVICE A VALVE TRAIN

I. Equipment and materials

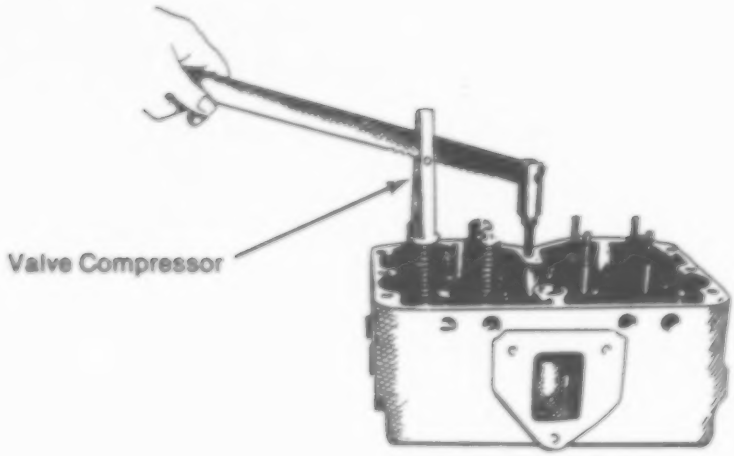
- A. Valve spring compressor
- B. Steam supply
- C. Air compressor
- D. Bench grinder
- E. 0 to 1-inch micrometer
- F. Valve spring tester
- G. Dial indicator
- H. Basic hand-tool set
- I. Board with set of numbered holes for valves
- J. Crocus cloth
- K. Eye protection
- L. Appropriate service manual

II. Procedure

- A. Remove valve
  1. Steam clean complete head assembly
  2. Dry with compressed air
  3. Place cylinder head in head-holding device or equivalent

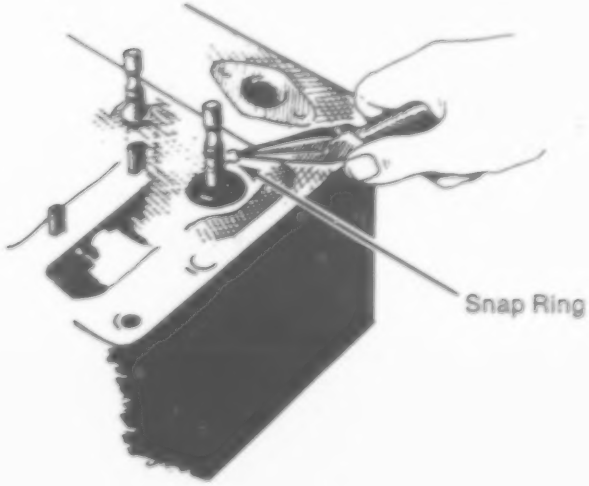
4. Compress one valve spring at a time with valve compressor (Figure 21)

FIGURE 21



5. Tap valve lightly to loosen; then remove split collar retainers
6. Remove spring cup
7. Remove spring
8. Remove snap ring and seal if used (Figure 22)

FIGURE 22



JOB SHEET #2

9. Remove valve from bottom of cylinder head

10. Use a board with a set of numbered holes drilled in it; place valves in holes in their correct order

(CAUTION: Do not mix.)

B. Clean valves

1. Hold each valve firmly against a wire wheel on a bench grinder, or use glass bead or sandblast method

2. Remove all carbon from valve head, face, and stem

3. Polish valve stems with crocus cloth

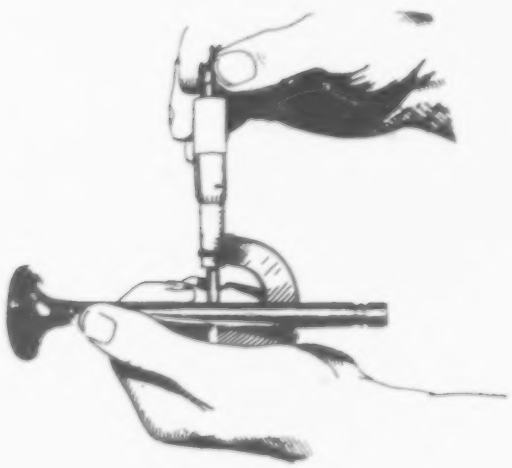
(NOTE: Do not use wire brush on surface of stem bearing.)

C. Inspect and test valves

1. Inspect valves

a. Use 0 to 1-inch micrometer to measure the valve stem (Figure 23)

FIGURE 23



b. If diameter is less than specified in manufacturer's manual, discard valve and valve guide

(NOTE: See Job Sheet #3 for valve guide replacement.)

JOB SHEET #3

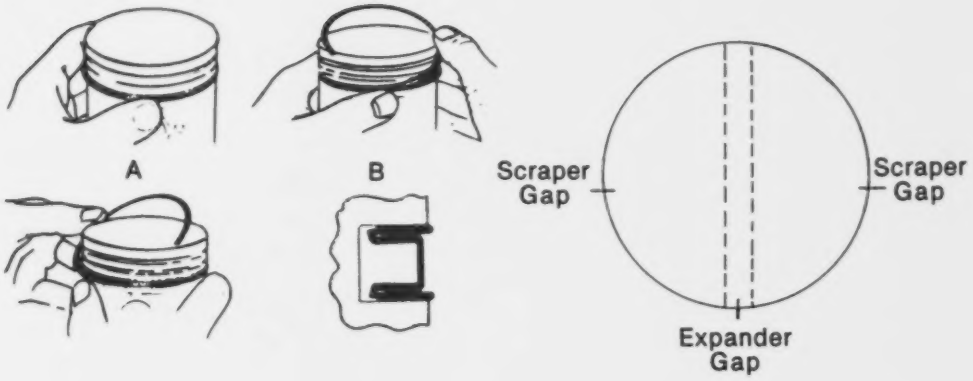
2. Install oil ring in lower groove (Figure 25)

   a. Place expander in groove with ends butted together in correct position

   b. Install oil ring lower scraper with ring gap 90 degrees to either side of expander gap

   c. Install oil ring upper scraper with ring gap 180 degrees from lower scraper gap

FIGURE 25



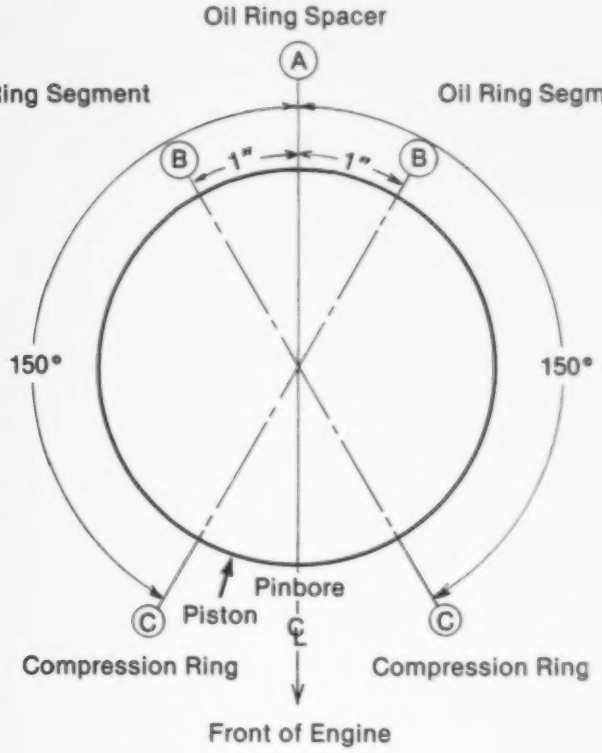
3. Install compression rings, using ring expander (Figure 26)

FIGURE 26

JOB SHEET #3

4. Position ring gap on piston (Figure 27)

FIGURE 27



E. Install piston in cylinder

(NOTE: Pour 1 quart of oil into the gallon can to provide a method for lubricating the pistons and ring assemblies.)

1. Dip piston and ring in can of oil

   (NOTE: Be sure to use a drain pan to catch any oil dripping from piston at the vise and engine.)

2. Secure piston in vise by lightly clamping connecting rod in vise with soft jaws

3. Open ring compressor enough to fit over piston rings easily

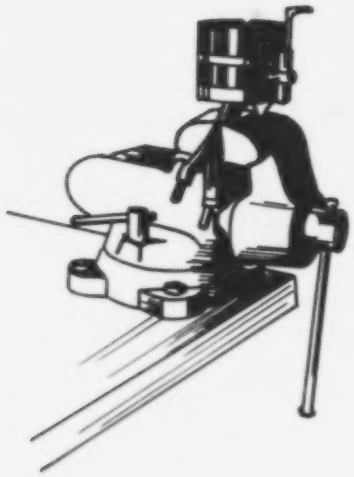
4. Place ring compressor over piston and ring assembly, with notches on compressor edge down

JOB SHEET #3

5. Tighten compressor slowly while keeping it straight (Figure 28)

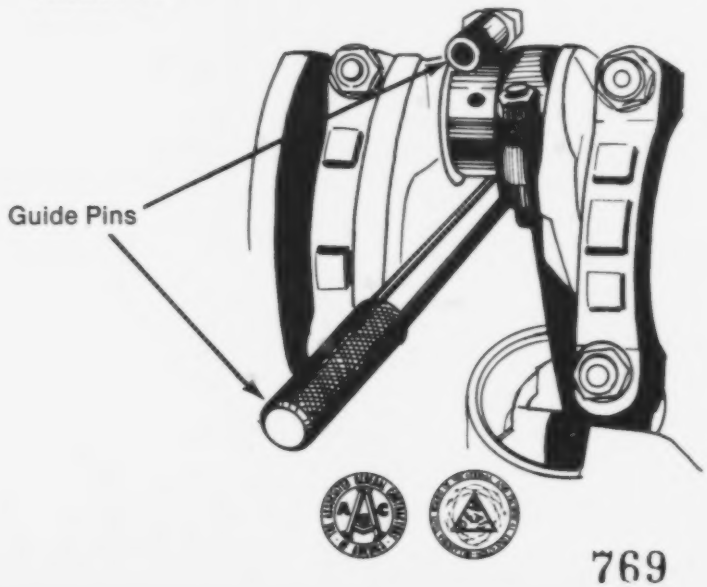
   (NOTE: To help the rings slip into place, occasionally tap the compressor very lightly while tightening. The compressor does not have to be extremely tight.)

FIGURE 28



6. Turn rod journal to its outermost position
7. Clean rod journal
8. Clean and lubricate cylinder
9. Install guide pin on rod bolts (Figure 29)

FIGURE 29



10. Insert rod and piston assembly into cylinder

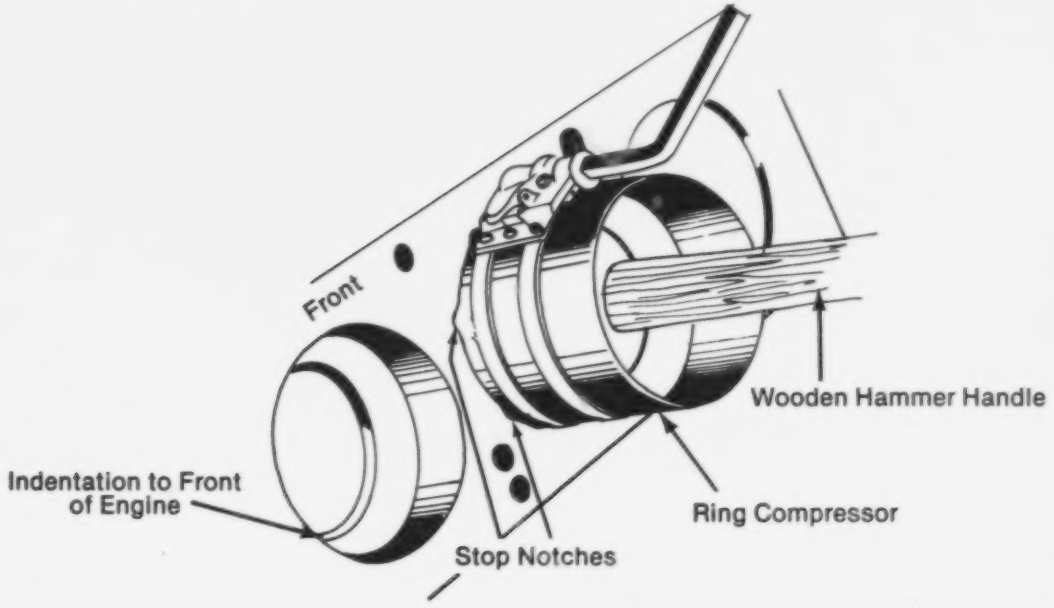
    (NOTE: Be sure that rod and piston assembly is in same numbered cylinder as number on the rod.)

11. Rotate piston so that front marking on piston is toward front of engine

12. Gently tap piston into cylinder with a wooden hammer handle (Figure 30)

    (NOTE: Watch to see that compressor stays straight and does not try to enter the cylinder.)

FIGURE 30



13. Stop tapping piston when top is flush with cylinder

F. Attach connecting rod to crankshaft journal

1. Clean connecting-rod bearing seat

2. Install bearing in rod and rod cap

   (CAUTION: Align the tang on insert bearing with groove in rod bore, and be sure that it is seated properly.)

JOB SHEET #3

3. Pull connecting rod up over crankshaft rod journal

   (CAUTION: Do not bump the journal surface with the rod bolts as this will damage the shaft.)

4. Remove guide pin set from bolts

5. Measure rod bearing clearance with Plastigauge

6. Clean Plastigauge from bearing and shaft

7. Lubricate rod bearings

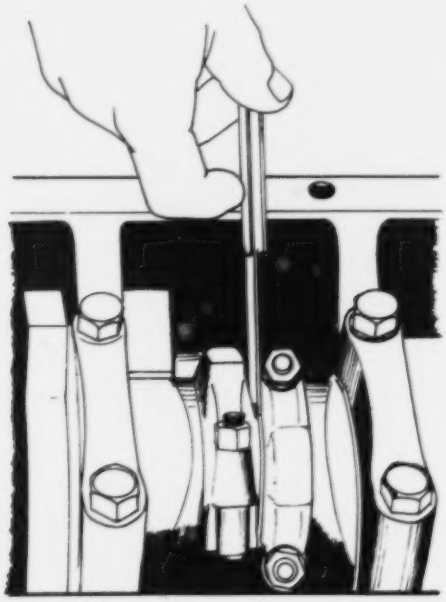
8. Install rod cap and torque to specifications

9. Turn crankshaft one complete turn to check for binding or excessive tightness after installing each piston assembly

10. Follow this same procedure for the remaining pistons

G. Check connecting rod side clearance; compare with specifications (Figure 31)

FIGURE 31



H. Clean work area; clean and put away all tools and equipment

ENGINE REASSEMBLY AND INSTALLATION
UNIT V

JOB SHEET #4 — INSTALL OIL PUMP, PICKUP SCREEN, AND OIL PAN

I. Equipment and materials

A. Engine from Job Sheet #3

B. Basic hand-tool set

C. Safety glasses

D. Gasket sealer

E. Lightweight motor oil, 20-W

F. Torque wrench

G. Silicone sealer

H. Engine repair stand

I. Appropriate service manual

II. Procedure

(NOTE: Rotate the engine on the engine repair stand so that crankcase is facing up.)

A. Set oil pump in can of oil used to soak pistons

B. Rotate pump drive shaft so that oil will be pulled through pump

C. Install oil pump

(NOTE: On some models, the pickup screen will have to be pressed onto the pump before the pump is installed. Others can be bolted on after pump installation.)

1. Place drive shaft on pump if pump is so equipped

2. Place pump on engine and start retaining bolts

3. Torque retaining bolts

4. Install pickup screen if not already installed

(NOTE: The screen should be properly aligned to fit close to the bottom of the pan.)

JOB SHEET #4

D. Install any special oil baffles or other special components

E. Install oil pan

1. Apply a light coat of sealer to block at pan gasket mating surface
2. Lay gasket on block while making sure that all ends are properly seated
3. Apply extra sealer at all gasket seams
4. Tap pan bolt holes flat using edge of workbench
5. Position oil pan on gasket
6. Start all pan bolts
7. Tighten all bolts to a very light pressure
8. Torque all bolts to manufacturer's specifications

   (CAUTION: Do not overtighten the bolts because this will mash the gasket apart.)
9. Tighten oil pan drain plug

F. Clean work area; clean and put away all tools and equipment

ENGINE REASSEMBLY AND INSTALLATION
UNIT V

JOB SHEET #5 — INSTALL CYLINDER HEAD, INTAKE MANIFOLD, AND EXHAUST MANIFOLD

I. Equipment and materials

A. Engine from Job Sheet #4

B. Basic hand-tool set

C. Safety glasses

D. Shop towels

E. Gasket sealer

F. Torque wrench

G. Removable cylinder-head guide dowels

H. Silicone cement

I. Engine repair stand

J. Appropriate service manual

II. Procedure

(NOTE: Rotate the engine repair stand to its normal upright position.)

A. Install valve lifters

1. Clean lifter bores in block

2. Lubricate outside of lifter

3. Place lifters in their respective bores

(NOTE: If camshaft and lifters are the same as those removed, lifters should be replaced in their original positions.)

4. Install lifter chamber cover on six-cylinder models

B. Install any baffles or vapor separators as necessary in lifter valley

C. Install cylinder heads

1. Clean cylinder block head-gasket surface

2. Install removable dowels if there are no dowel pins on the block to align gasket and head

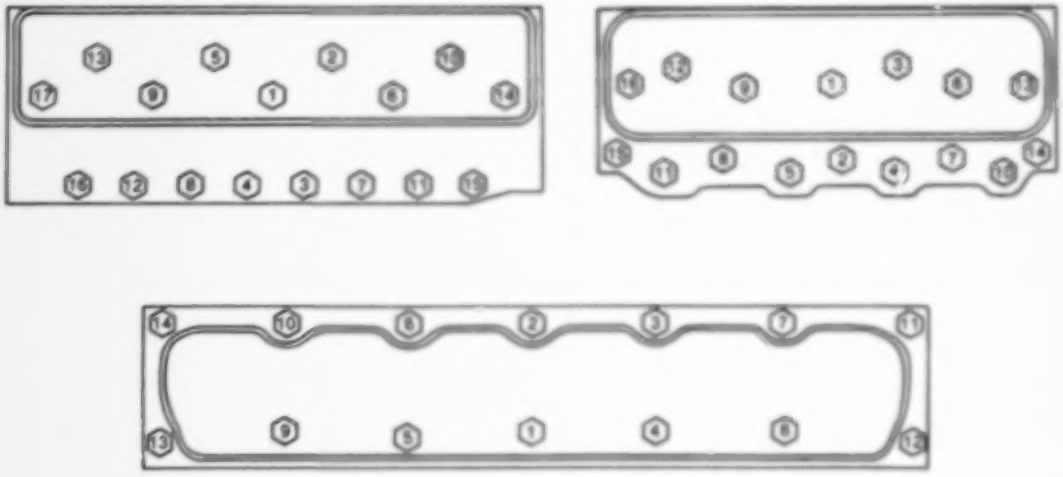
3. Apply appropriate gasket sealer to head gasket

JOB SHEET #5

4. Place head gasket on cylinder block
5. Clean cylinder head gasket mating surface
6. Place cylinder head carefully on block
7. Place head bolts in their proper locations according to length

   (NOTE: Head bolts that screw into the water jacket must have a non-hardening sealer on the threads to prevent coolant seepage.)
8. Tighten head bolts until they just touch head
9. Torque head bolts to one-half the specified torque in a sequence recommended by manufacturer
10. In sequence, retorque head bolts to three-fourths the specified torque (Figure 32)

FIGURE 32



JOB SHEET #5

11. In sequence, retorque head bolts to full specified torque

12. Follow the procedure outlined in step C for installing the other cylinder head on V-engine

D. Install valve rocker arms and push rods

1. Place push rods through guides in cylinder head and into lifter recess

(NOTE: Be sure that the push rods are in the proper hole and are positioned with correct end up.)

2. Place rocker arms on head

3. As rocker arm bolts are tightened, align push rods with rocker arms

4. Torque retaining bolts in rocker arm stand

(NOTE: Follow valve adjustment procedures outlined by the vehicle's manufacturer.)

(CAUTION: On models where rocker arm pivots on a stud, to prevent damage to the valve train, tighten only until the slack is taken out of the rocker arm.)

E. Install intake manifold (V-8 model)

(NOTE: On most six-cylinder engines, the exhaust and intake manifold will be installed as one component.)

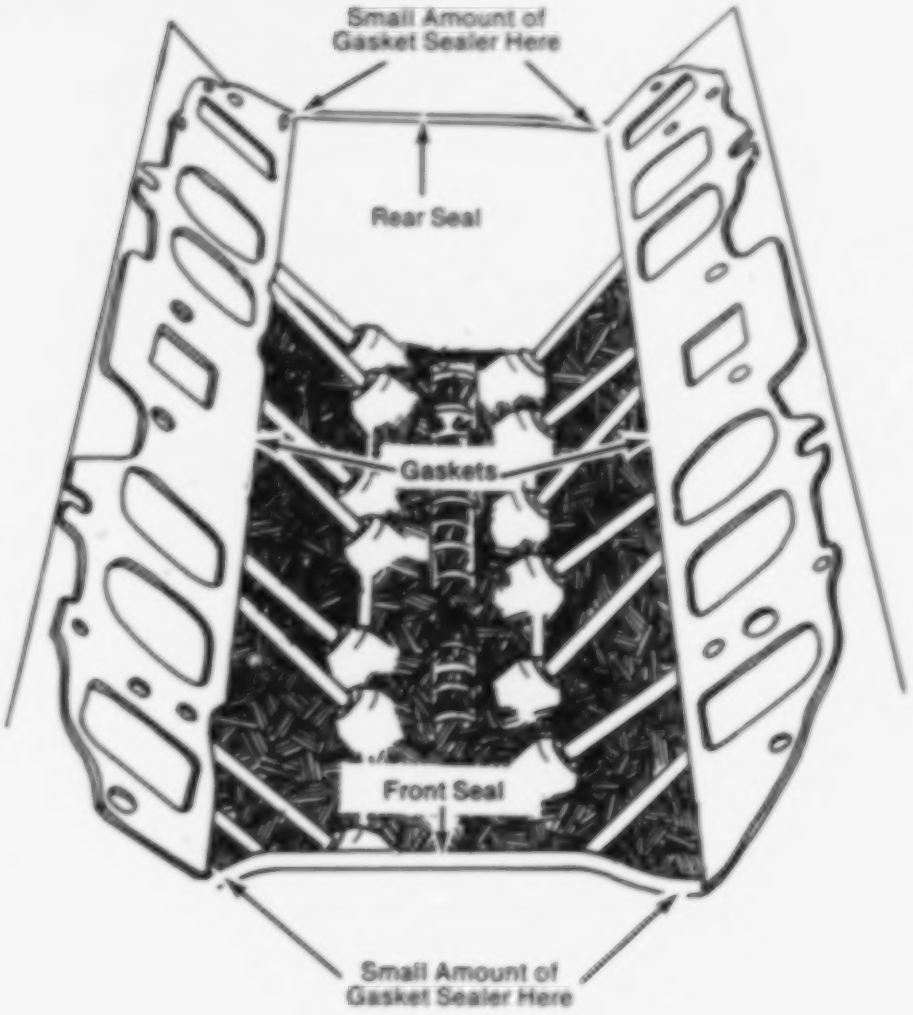
1. Wipe clean the intake manifold gasket surfaces on manifold and engine

2. Install end rail gaskets on V-engines (See Figure 33)

3. Install side gaskets on V-engines or intake gasket on in-line-type engines

4. Place small amount of gasket sealer in each corner where the gaskets overlap each other (Figure 33)

FIGURE 33



5. Carefully set intake manifold on engine

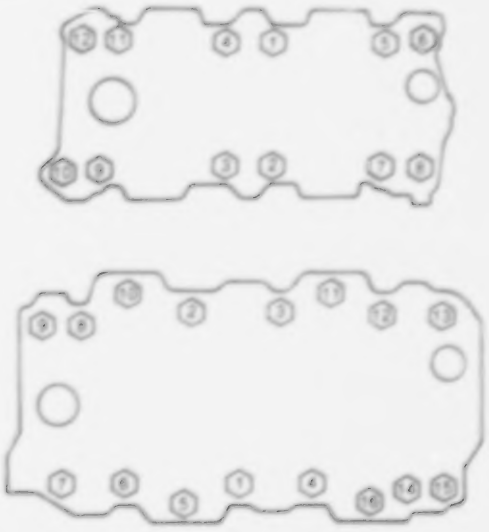
6. Install all manifold bolts

JOB SHEET #5

7. Torque bolts in sequence (Figure 34)

(NOTE: Some manifold bolts will probably have to be removed later to attach accessories.)

FIGURE 34



Torque Sequence for Two Basic V-8 Manifolds

F. Install exhaust manifolds

(NOTE: Most six-cylinder exhaust manifolds are either a part of the cylinder head or are installed as a component part of the intake manifold.)

1. Wipe clean cylinder head and exhaust manifold gasket surfaces

2. Attach manifolds with gasket to cylinder head

(NOTE: Some models do not require an exhaust manifold gasket. Do not use gasket sealer on exhaust gaskets.)

3. Torque manifold attaching bolts in sequence

JOB SHEET #5

G. Adjust valves

(NOTE: Lifters must be on the heel of the cam lobe to obtain correct valve adjustment. To accomplish this, the engine crankshaft should be turned to place the No. 1 piston in firing position. At this position, one-half of the valves can be adjusted. Rotate the crankshaft one complete turn, and the other half of the valves can be adjusted. Use the following steps as a guide.)

1. Locate No. 1 cylinder in firing order

2. Rotate engine crankshaft in direction of normal operation; watch for alignment of timing mark on crankshaft pulley with zero mark on timing cover and movement of the No. 1 cylinder valves

   (NOTE: If valves *are not* moving as the timing marks align, the valves can be adjusted. If the valves *are* moving as the timing marks align, rotate one complete turn before adjusting valves.)

3. Mark adjustment for hydraulic lifter valves (Figure 35)

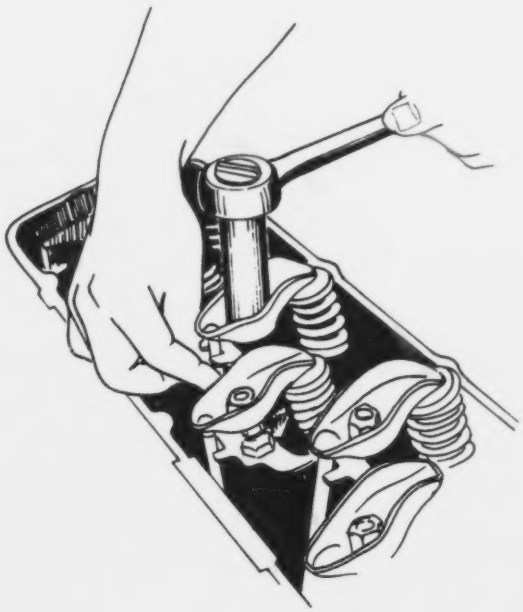
   a. Back off adjusting nut until lash is felt at push rod

      (NOTE: Lash can be determined by checking push-rod side play while turning adjusting nut.)

   b. Tighten adjusting nut until zero clearance between push rod and rocker arm is obtained

   c. Tighten adjusting nut the additional number of turns recommended by manufacturer

FIGURE 35



JOB SHEET #5

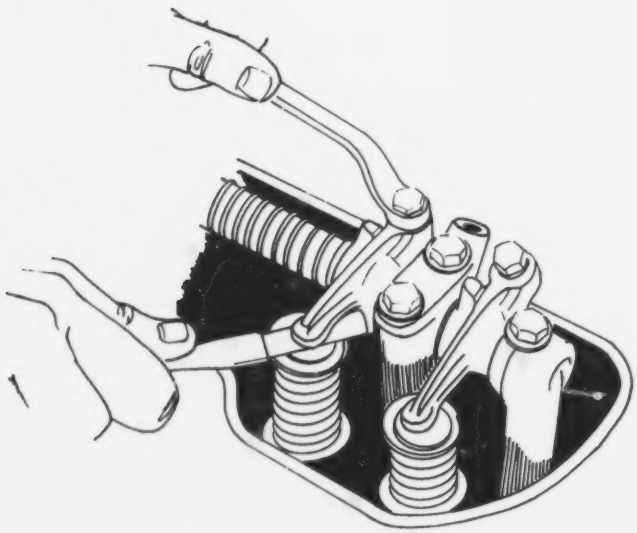
4. Make adjustment for solid lifter valves (Figure 36)

   a. Place feeler gauge of correct thickness between rocker arm and valve stem

   b. Tighten adjuster until a slight drag is felt while moving feeler gauge

   c. Tighten locknut if vehicle is so equipped

FIGURE 36



H. Clean work area; clean and put away all tools and equipment

ENGINE REASSEMBLY AND INSTALLATION
UNIT V

JOB SHEET #6 — INSTALL ENGINE ACCESSORY COMPONENTS

I. Equipment and materials

A. Engine from Job Sheet #5

B. Basic hand-tool set

C. Safety glasses

D. Clean shop towels

E. Torque wrench

F. Gasket sealer

G. Oil filter

H. Appropriate service manual

II. Procedure

(NOTE: This job sheet presents in sequence the procedures for installing engine accessory components and will cover only the generally used components.)

A. Install fuel pump

1. Clean gasket surfaces
2. Apply sealer to fuel pump gasket surface
3. Place gasket on pump
4. Install attaching bolts through pump and gasket holes
5. Install fuel pump push rod if engine is so equipped

   (NOTE: On models with push rods, tighten pump bolts very evenly to avoid the pump lever binding on the push rod and bending it.)
6. Install pump; torque bolts

B. Install water pump

1. Clean gasket surfaces
2. Apply gasket sealer to both pump and engine gasket surfaces
3. Place gasket on pump

JOB SHEET #6

4. Start at least two bolts through pump and gasket
5. Install pump
6. Torque pump attaching bolts

C. Install front motor mount

D. Install oil filter with heat exchanger

1. Install assembled filter head to heat-exchanger body; torque bolts to 35 to 42 foot-pounds
2. Install filter base to heat-exchanger body; torque bolts to 35 to 42 foot-pounds
3. Install heat-exchanger assembly to engine block; torque bolts to 80 to 96 foot-pounds
4. Install outlet tube
5. Intall new oil filter

   (NOTE: Hand-tighten filter only one-half to three-fourths of a turn to obtain a proper seal.)
6. Close drain valves on heat exchanger, engine block, and radiator

   (CAUTION: Be sure to fill system with coolant and engine oil before starting engine.)

E. Install alternator and drive belt; adjust tension on drive belt

(NOTE: Wires can not be connected until engine is installed.)

F. Install any other accessories that were disconnected when engine was removed

G. Clean work area; clean and put away all tools and equipment

ENGINE REASSEMBLY AND INSTALLATION
UNIT V

JOB SHEET #7 — INSTALL ENGINE IN CRAWLER TRACTOR

I. Equpment and materials

A. Crawler tractor engine on engine repair stand

B. Basic hand-tool set

C. Engine hoist

D. Engine lift adapter

E. Torque wrench

F. Tubing wrench

G. Shop towels

H. Grease gun

I. Lithium-based grease (soap base)

J. Appropriate service manual

II. Procedure

(NOTE: This procedure is written specifically for a JI Case 850 Crawler. Procedures may vary with other manufacturers' equipment.)

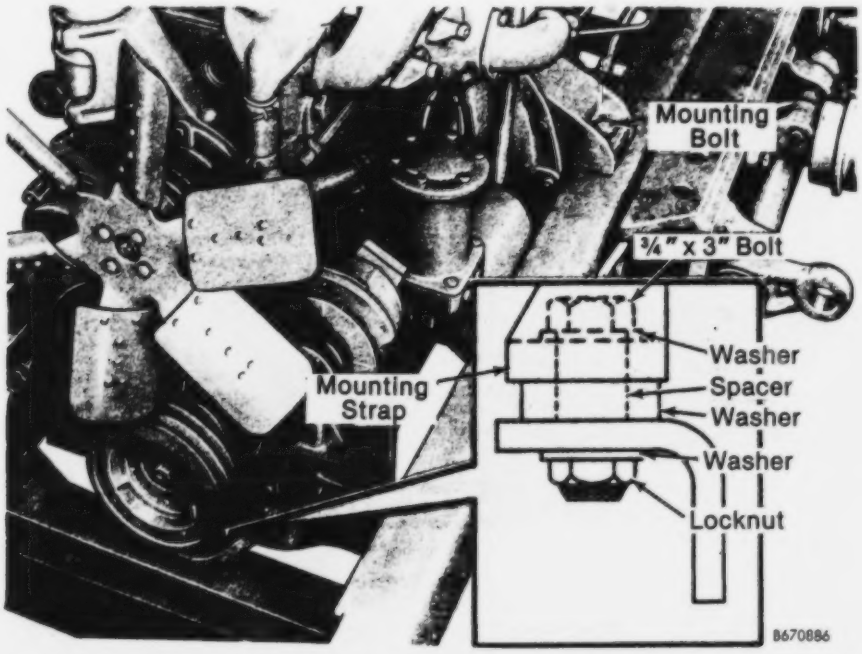
A. Attach engine lift adapter to engine; connect hoist to adapter

B. Lift engine enough to take load off engine repair stand; disconnect stand

JOB SHEET #7

C. Move engine into position for mounting on engine frame (Figure 37)

FIGURE 37



Used with permission of JI Case, a Tenneco Company.

D. Attach engine to engine mounting strap; remove hoist and lift adapter

E. Install drive shaft

1. Attach drive shaft to torque converter and transmission yokes
2. Torque cap screws to 45 foot-pounds
3. Lubricate universal joint with soap-based lithium grease

   (CAUTION: Do not use a high-pressure gun.)
4. Remove plug on drive shaft yoke and install a grease fitting
5. Fill yoke with soap-based lithium grease

F. Connect hydraulic lines and tubes between torque converter and transmission

G. Connect lines from instrument panel to torque converter

H. Attach battery ground cable to left side of torque converter housing

JOB SHEET #7

I. Install radiator

J. Connect oil pressure gauge, engine temperature gauge, and tachometer cable lines to engine

K. Connect throttle control rod to rear of fuel injection pump and to throttle lever at instrument panel

L. Connect fuel and fuel vent lines to their fittings at rear of engine

M. Clamp main wiring harness conduit to engine, and connect plug to voltage regulator

N. Connect all wiring

O. Install battery

(CAUTION: Connect ground or negative cable last to prevent possible electrical arc.)

P. Install floorboard and connect foot throttle linkage

Q. Double-check all connections

(NOTE: Proceed to Job Sheet #8 for adjusting and starting engine.)

ENGINE REASSEMBLY AND INSTALLATION
UNIT V

JOB SHEET #8 — ADJUST AND START NEWLY INSTALLED CRAWLER TRACTOR ENGINE

I. Tools and equipment

A. Crawler tractor from Job Sheet #7

B. Basic hand tool-set

C. Safety glasses

D. Timing light

E. Tach-dwell tester

F. Feeler gauge set

G. Clean shop towels

H. Gasket sealer

I. Appropriate service manual

II. Procedure

A. Install air cleaner and muffler

B. Fill crankcase with specified amount and grade of oil

C. Close coolant system drain plugs

D. Fill cooling system with coolant

(NOTE: Leave radiator cap loose so that coolant level can be checked easily after engine has run for a short time.)

E. Crank engine for approximately twenty seconds

F. Check for any coolant or oil leaks; repair if necessary

G. Road test crawler tractor accompanied by instructor

H. Perform break-in procedure on road test

I. After road test, readjust engine idle

J. Install hood and latch guards

JOB SHEET #8

K. Install air cleaner cap and rain cap

L. Install side panels, engine panels, and brush guards

M. Park crawler tractor in designated area

N. Clean and put away all tools and equipment

ENGINE REASSEMBLY AND INSTALLATION
UNIT V

TEST

NAME _____ SCORE _____

1. Match to their correct definitions terms associated with engine reassembly and installation. Write the correct numbers in the blanks.

_____a.	Procedure to help frictional parts in a new or rebuilt engine adjust to each other	1. Lithium-based grease
_____b.	Top dead center; position of piston at its highest travel in cylinder	2. Road test
_____c.	Lithium-based lubricant with high impact and temperature stability qualities	3. TDC
_____d.	Systematic method of testing a vehicle under varied conditions to determine its general condition	4. Torque sequence
_____e.	Tightening pattern that draws two components together evenly at all points	5. Lug an engine
_____f.	Flat strip, usually of cork or metal or both, placed between two machined surfaces to provide a tight seal	6. Gasket
_____g.	Acceptable variation from a standard fit or adjustment	7. Engine break-in
_____h.	To load an engine so heavily that under acceleration it does not gain speed	8. Tolerance

2. State safety precautions to observe during engine installation.

a. _____

b. _____

c. _____

d. _____

e. _____

TEST

3. Identify tools used in engine reassembly. Write the correct names in the blanks.

Camshaft-bearing remover and installer tool
Rear main-bearing-seal tool
Push-rod installer tool
Valve-lifter installer tool
Vibration damper tool
Ring expander
Ring compressor
Torque wrench
Piston-pin press

a. _____

b. _____

c. _____

d. _____

e. _____

f. _____

g. _____

h. _____

i. _____

TEST

4. List three reasons for torquing bolts to specifications.

   a. _____

   b. _____

   c. _____

5. List three guidelines to follow when installing an engine.

   a. _____

   b. _____

   c. _____

6. List items to check or adjust before starting a new or rebuilt engine.

   a. _____

   b. _____

   c. _____

   d. _____

   e. _____

   f. _____

7. State three break-in procedures for an engine.

   a. _____

   _____

   b. _____

   _____

   c. _____

   _____

   _____

TEST

(NOTE: Test question 8 lists the job sheets. They are an important part of this test. If they have not been completed, check with your instructor.)

8. Demonstrate the ability to

   a. Install camshaft and bearings.

   b. Install crankshaft, bearings, timing gears, and timing cover.

   c. Install pistons and connecting-rod assemblies.

   d. Install oil pump, pickup screen, and oil pan.

   e. Install cylinder head, intake manifold, and exhaust manifold.

   f. Install engine accessory components.

   g. Install engine in crawler tractor.

   h. Adjust and start newly installed crawler tractor engine.

ENGINE REASSEMBLY AND INSTALLATION
UNIT V

ANSWERS TO TEST

1.

a.	7	d.	2	g.	8
b.	3	e.	4	h.	5
c.	1	f.	6		

2.
a. Do not spill gasoline near engine
b. Do not cause an electrical arc near battery
c. Do not lift heavy engine components without assistance
d. Keep clear of engine while it is on hoist
e. Do not work under vehicle while engine is on hoist

3.
a. Ring compressor
b. Vibration damper tool
c. Ring expander
d. Valve-lifter installer tool
e. Torque wrench
f. Camshaft-bearing remover and installer tool
g. Push-rod installer tool
h. Rear main-bearing-seal installer
i. Piston-pin press

4. Answer should include any three of the following
a. Preventing overtightening and stretching of bolts
b. Preventing distortion of mating surfaces between parts

ANSWERS TO TEST

c. Preventing thread damage

d. Preventing leaks from uneven mating surfaces

e. Preventing cylinder wall distortion from overtightened head bolts

5. Answer should include any three of the following

a. Have ample work area for equipment and vehicle

b. Have a precise plan of action

c. Obtain proper tools and equipment

d. Have all specifications for replacement and adjustments

e. Know your job

6. a. Check coolant level

b. Check oil level

c. Adjust valves

d. Adjust ignition-point dwell (gasoline engine)

e. Adjust ignition timing

f. Adjust engine idle

7. Answer should include any three of the following

a. Make engine tune-up adjustments to correct settings

b. Check all fluid levels

c. Check engine and its accessories for oil, coolant, and fluid leaks

d. Road test vehicle

1) Bring engine to operating temperature

2) Accelerate vehicle at full throttle until about half speed is reached; then ease up and let engine smooth out for at least two miles

ANSWERS TO TEST

3) Repeat this road-test procedure approximately ten times

8. Performance skills evaluated to the satisfaction of the instructor

LUBRICATION SYSTEMS
UNIT I

UNIT OBJECTIVE

After completing this unit, the student should be able to identify components of the lubrication system and know their purposes, change oil, change a filter, and check and adjust oil pressure. The student will show this knowledge by completing job sheets and unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match to their correct definitions terms associated with lubrication systems.
2. List purposes of the lubrication system.
3. Label components of engine lubrication systems.
4. Match components of the engine lubrication system to their correct purposes.
5. List types of lubrication systems.
6. Identify types of oil filters.
7. List types of oil pumps.
8. State guidelines to consider when selecting engine oil.
9. Match engine-oil additives to their correct functions.
10. Select from a list sources of oil contamination.
11. Describe circulation of water and oil in an oil cooler.
12. Describe types of oil-pressure indication systems.
13. Demonstrate the ability to
    a. Change oil in an engine.
    b. Change an oil filter.
    c. Check and adjust oil pressure on a live engine.

LUBRICATION SYSTEMS
UNIT I

SUGGESTED ACTIVITIES

I. Suggested activities

A. Order films and other materials planned to supplement unit.

(NOTE: Manufacturers are excellent sources for slide and film presentations on lubrication systems. Write directly to the appropriate company or manufacturer. Check with manufacturers and equipment dealers for visual aids that demonstrate lubrication-system operations.)

B. Gather materials and equipment for job sheet demonstrations.

C. Obtain transparencies.

(NOTE: Transparencies are available from AGC and CIMC.)

D. Provide students with objective sheet.

E. Discuss unit and specific objectives.

F. Provide students with information and job sheets.

G. Discuss information sheet.

H. Demonstrate and discuss procedures outlined in the job sheets.

I. Give test.

J. Complete appropriate section of competency profiles.

(NOTE: Competency profiles are available from AGC and CIMC.)

II. Instructional materials

A. Objective sheet

B. Suggested activities

C. Information sheet

D. Transparency masters

1. TM #1 — Components of the Engine Lubrication System

2. TM #2 — Components of the Engine Lubrication System (Continued)

SUGGESTED ACTIVITIES

3. TM #3 — Types of Lubrication Systems
4. TM #4 — Types of Lubrication Systems (Continued)
5. TM #5 — Types of Oil Pumps
6. TM #6 — Types of Oil Pumps (Continued)
7. TM #7 — Types of Oil Pumps (Continued)
8. TM #8 — Oil Coolers
9. TM #9 — Oil-Pressure Indication Systems: Mechanical
10. TM #10 — Oil-Pressure Indication Systems: Electrical
11. TM #11 — Oil-Pressure Indication Systems: Electrical (Continued)

E. Job sheets

1. Job Sheet #1 — Change Oil in an Engine
2. Job Sheet #2 — Change an Oil Filter
3. Job Sheet #3 — Check and Adjust Oil Pressure on a Live Engine

F. Test

G. Answers to test

III. Unit references

A. Armstrong, Ivan J. *Auto Mechanics,* Vol. I. Stillwater, Oklahoma: State Department of Vocational and Technical Education/Curriculum and Instructional Materials Center, 1976.

B. Foutes, William A. *Diesel Engine Mechanics.* Stillwater, Oklahoma: Mid-America Vocational Curriculum Consortium, Inc., 1977.

C. Foutes, William A. *Diesel Mechanics: Fundamentals.* Stillwater, Oklahoma: Mid-America Vocational Curriculum Consortium, Inc., 1982.

D. Hendrix, Laborn J. "Bud." *Heavy Equipment Operator Instructional Materials,* Vol. I. Stillwater, Oklahoma: State Department of Vocational and Technical Education/Curriculum and Instructional Materials Center, 1981.

LUBRICATION SYSTEMS
UNIT I

INFORMATION SHEET

I. Terms and definitions

A. Antifreeze — Material added to coolant to prevent freezing

B. Friction — Resistance to movement between any two objects placed in contact with each other

C. Lubricant — Substance that reduces friction between surfaces

D. Multiviscosity — Measure of the ability of an oil to meet the low-temperature requirements of a light oil and the high-temperature requirements of a heavy oil

E. Sludge — Muddy or slushy deposit or sediment

F. Viscosity — Measure of the ability of an oil to resist flowing

G. Viscosity index — Measure of the ability of an oil to resist changes in viscosity when heated

II. Purposes of the lubrication system

A. Lubricating moving parts to minimize friction

B. Acting as cooling agent to dissipate heat from engine parts

C. Forming a seal between piston rings and cylinder walls

D. Cleaning and flushing moving parts

E. Absorbing shock between bearings and other parts

F. Deadening engine noise

INFORMATION SHEET

III. Components of engine lubrication systems (Figures 1 and 2; Transparencies #1 and #2)

FIGURE 1 **Full-Flow System**

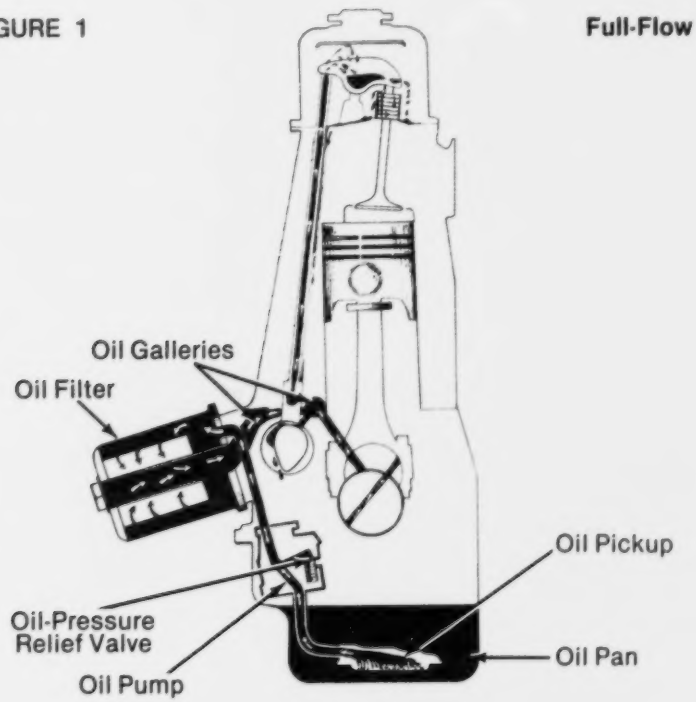
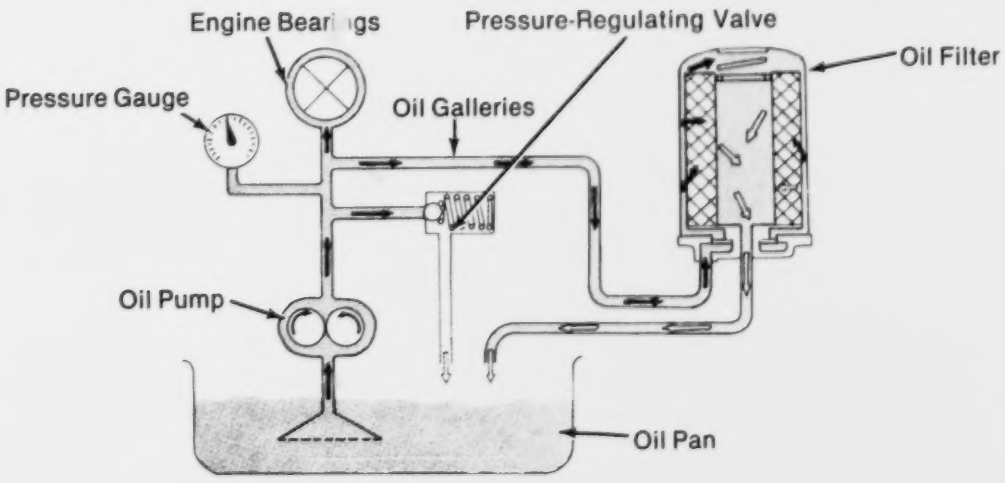


FIGURE 2 **Partial-Flow System**



INFORMATION SHEET

IV. Purposes of components of the engine lubrication system

A. Oil galleries — Carrying engine oil from one area to another

B. Oil filter — Straining engine oil to remove abrasive particles

C. Oil-pressure relief valve or regulating valve — Limiting maximum oil pressure

D. Oil pump — Forcing oil under pressure to various parts of engine

E. Oil pickup — Allowing pump to pick up oil from oil pan

F. Oil pan — Providing reservoir for engine oil

G. Pressure gauge — Indicating oil pressure during engine operation

V. Types of lubrication systems (Transparencies #3 and #4)

A. Circulating splash

B. Internal force-feed and splash

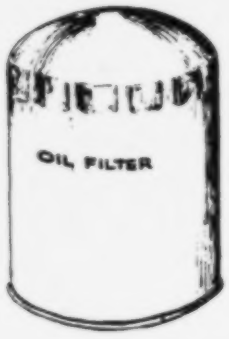
C. Full internal force-feed

(NOTE: The full internal force-feed system, in addition to other parts, supplies oil under pressure to the piston pins.)

VI. Types of oil filters (Figures 3-6)

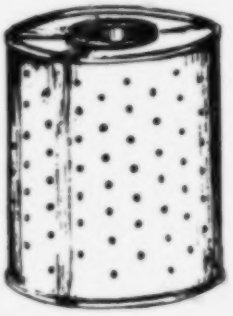
A. Sealed cartridge

FIGURE 3



B. Replaceable element

FIGURE 4



INFORMATION SHEET

C. Surface filter, wire mesh-type

FIGURE 5

D. Depth filter, cotton waste-type

FIGURE 6

VII. Types of oil pumps (Transparencies #5-#7)

A. Gear

B. Rotor

C. Vane

(NOTE: All are positive-displacement pumps.)

VIII. Guidelines to consider when selecting engine oil

A. Use oil of the proper viscosity for average temperature at which vehicle will operate

B. Use oil of the proper service rating as recommended by manufacturer

(NOTE: The service rating should be equal to or better than that recommended by the engine manufacturer.)

C. Select oils that have been service tested

(CAUTION: Do not mix oils of various service or viscosity ratings.)

IX. Engine-oil additives and their functions

A. Anticorrosion — Protects bearings and other metal surfaces from corrosion by acids created by combustion gases in crankcase

B. Oxidation inhibitor — Protects oil molecules from combining with oxygen, thus stops formation of acid, varnish, and sludge

C. Antirust — Clings to metal surfaces and repels water droplets to prevent rusting while engine is not in operation

INFORMATION SHEET

D. Viscosity-index improver — Helps oil give top lubricating protection at both high and low temperatures by giving the oil the beneficial properties of both light and heavy oils

E. Pour-point depressant — Prevents wax particles in oil from getting too thick in cold temperatures or too thin in hot temperatures

F. Extreme pressure — Ensures lubrication where extreme pressures are encountered

G. Detergent dispersant — Suspends particles of contaminants in oil to keep metal surfaces clean and to prevent deposit formation

H. Foam inhibitor — Prevents formation in oil of air bubbles that would restrict lubrication

X. Sources of oil contamination

A. Storage and handling

B. Dust in air breathed into engine

C. Improper engine warm-up

D. Antifreeze leaking into oil supply

E. Oxidation

F. Carbon particles

G. Engine wear

H. Fuel dilution

XI. Circulation of water and oil in an oil cooler (Transparency #8)

A. Internally mounted — Engine coolant is pumped through oil cooler mounted in crankcase, then back to radiator where heat is dissipated

B. Externally mounted — Both water and oil are pumped through oil cooler

(NOTE: Oil coolers are also known as *heat exchangers*.)

XII. Types of oil-pressure indication systems (Transparencies #9-#11)

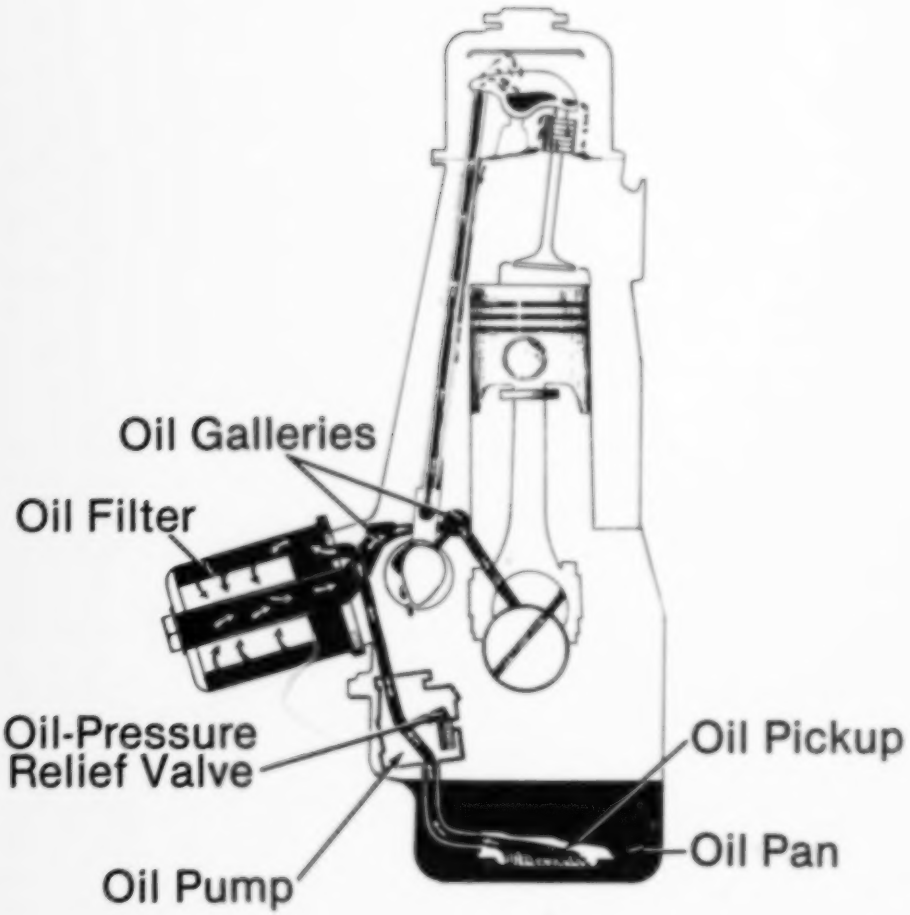
A. Mechanical — Bourdon tube gauge; tube straightens when pressure is applied

B. Electrical — Sending unit is at pressure source; indicating gauge is on control panel

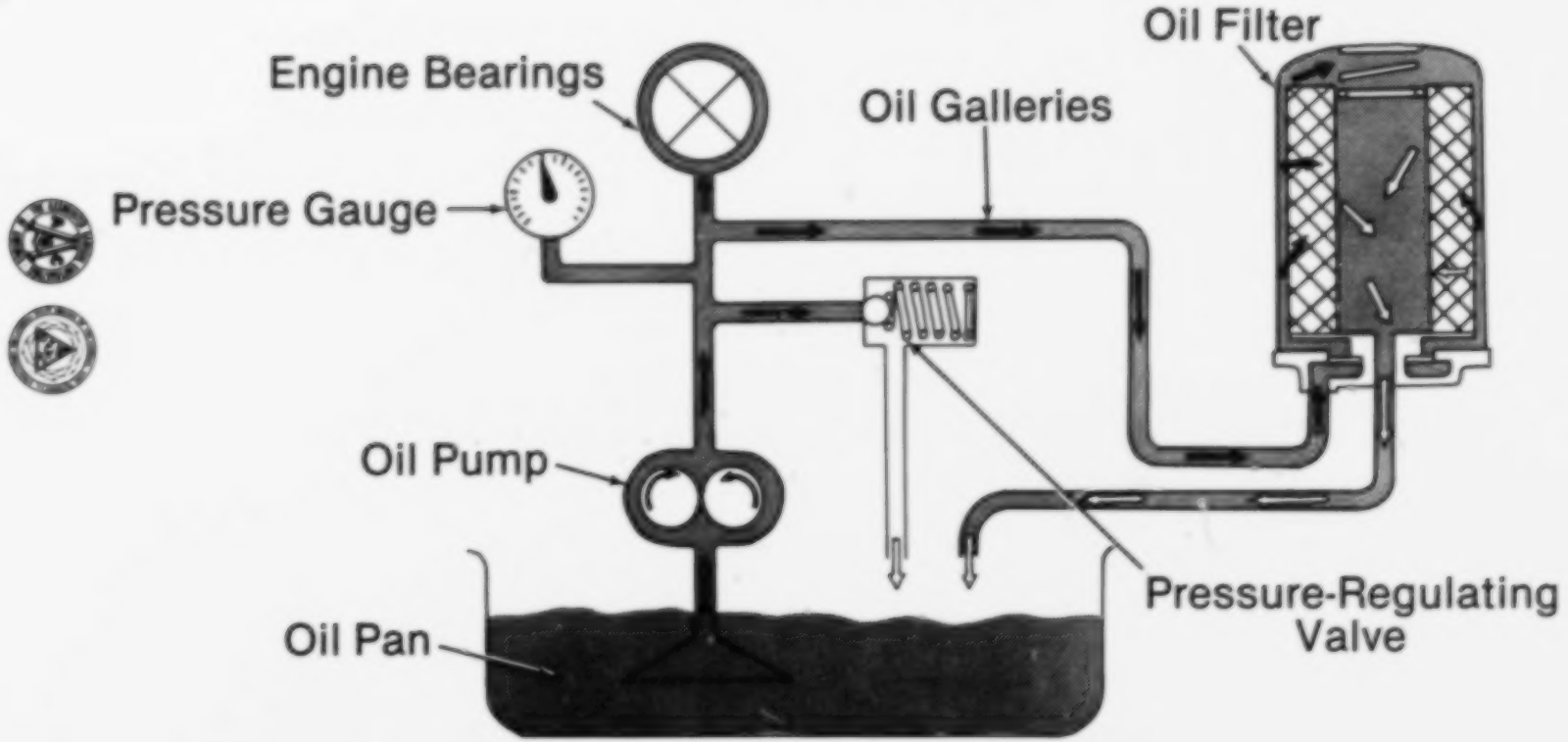
(NOTE: The three types of electrical indicating systems are electromagnetic coil, heating coil, and pressure-switch system.)

Components of the Engine Lubrication System

Full-Flow System

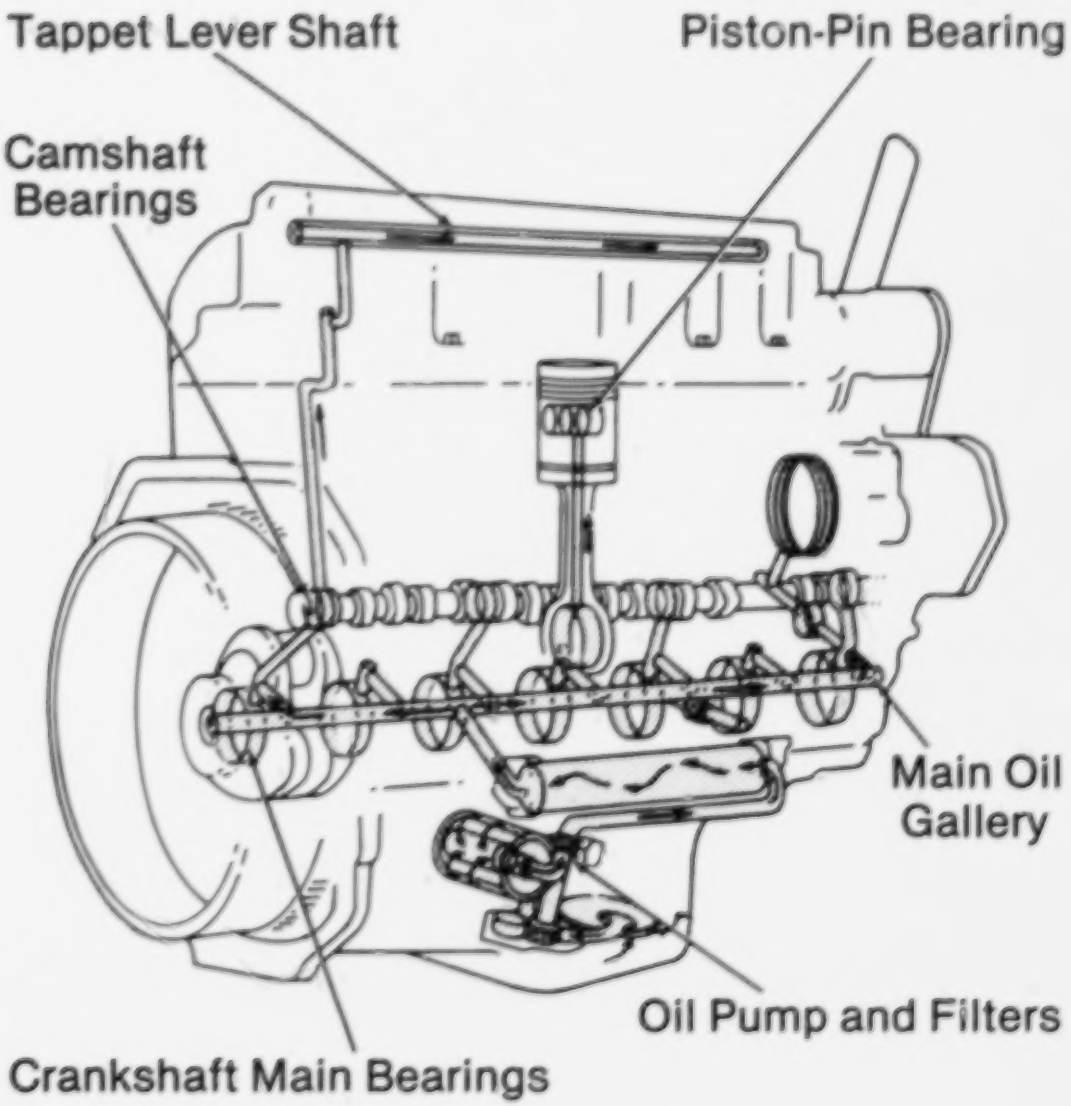


Components of the Engine Lubrication System
(Continued)
Partial-Flow System



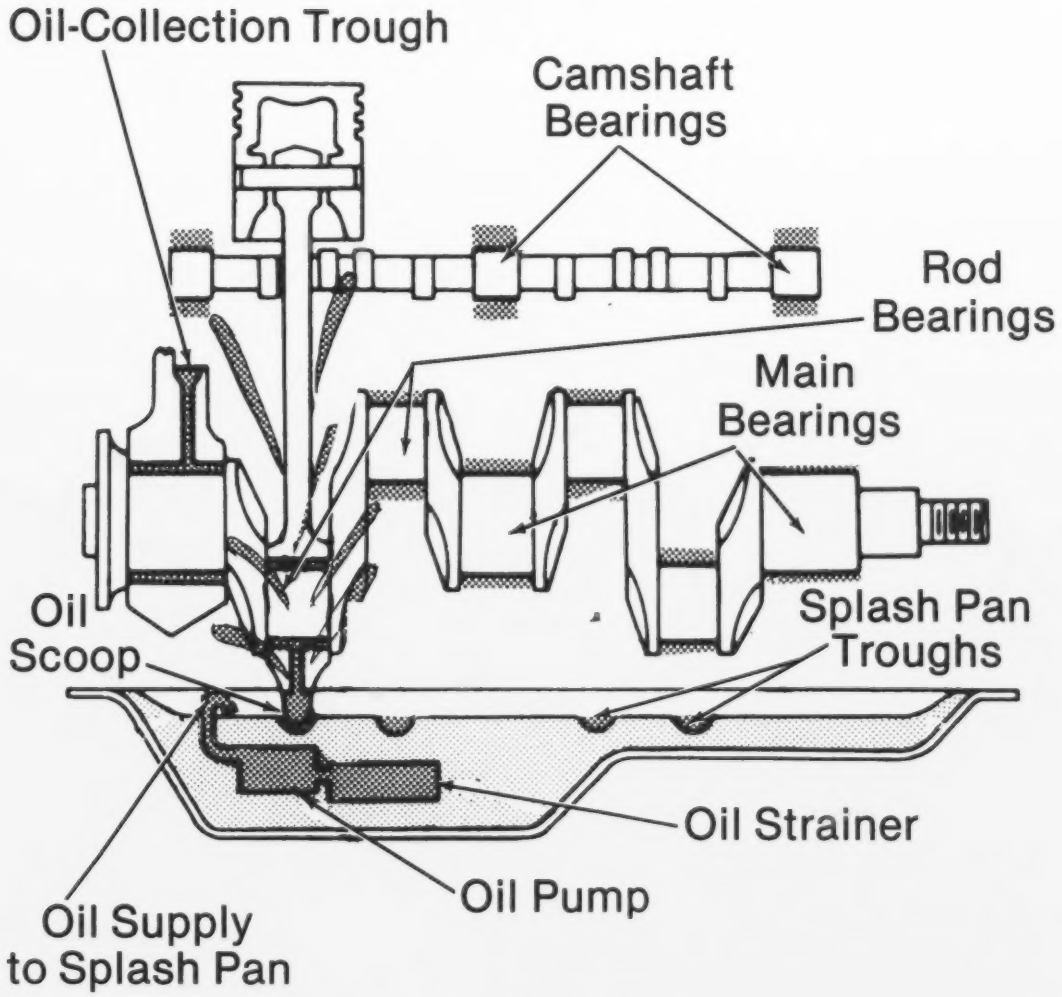
Types of Lubrication Systems

Full Internal Force-Feed System

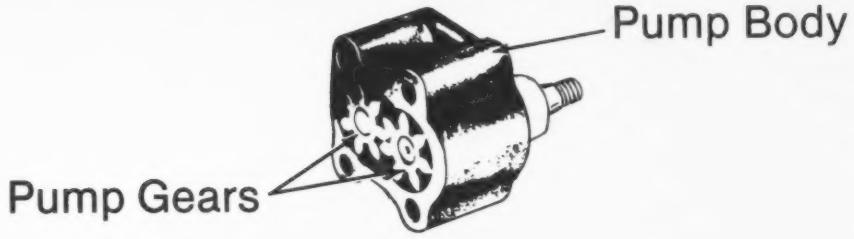


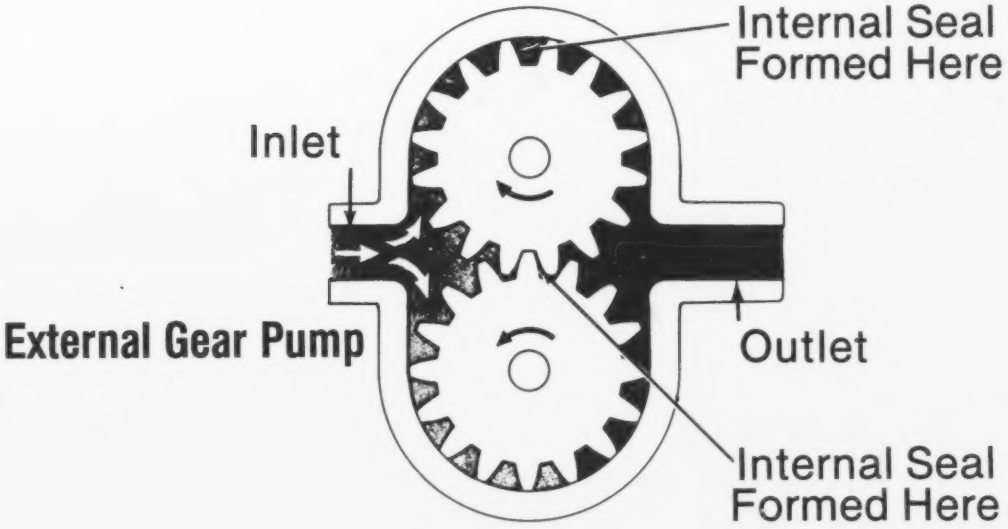
Types of Lubrication Systems
(Continued)

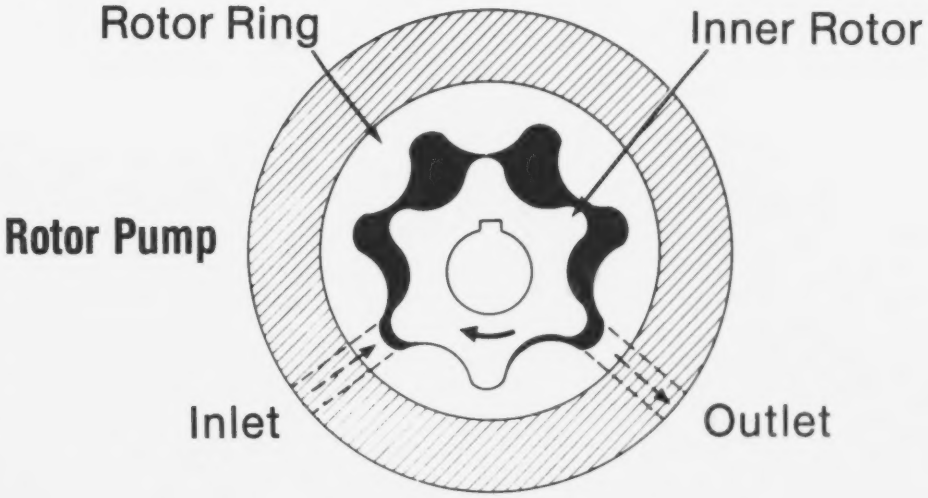
Circulating Splash System



Types of Oil Pumps

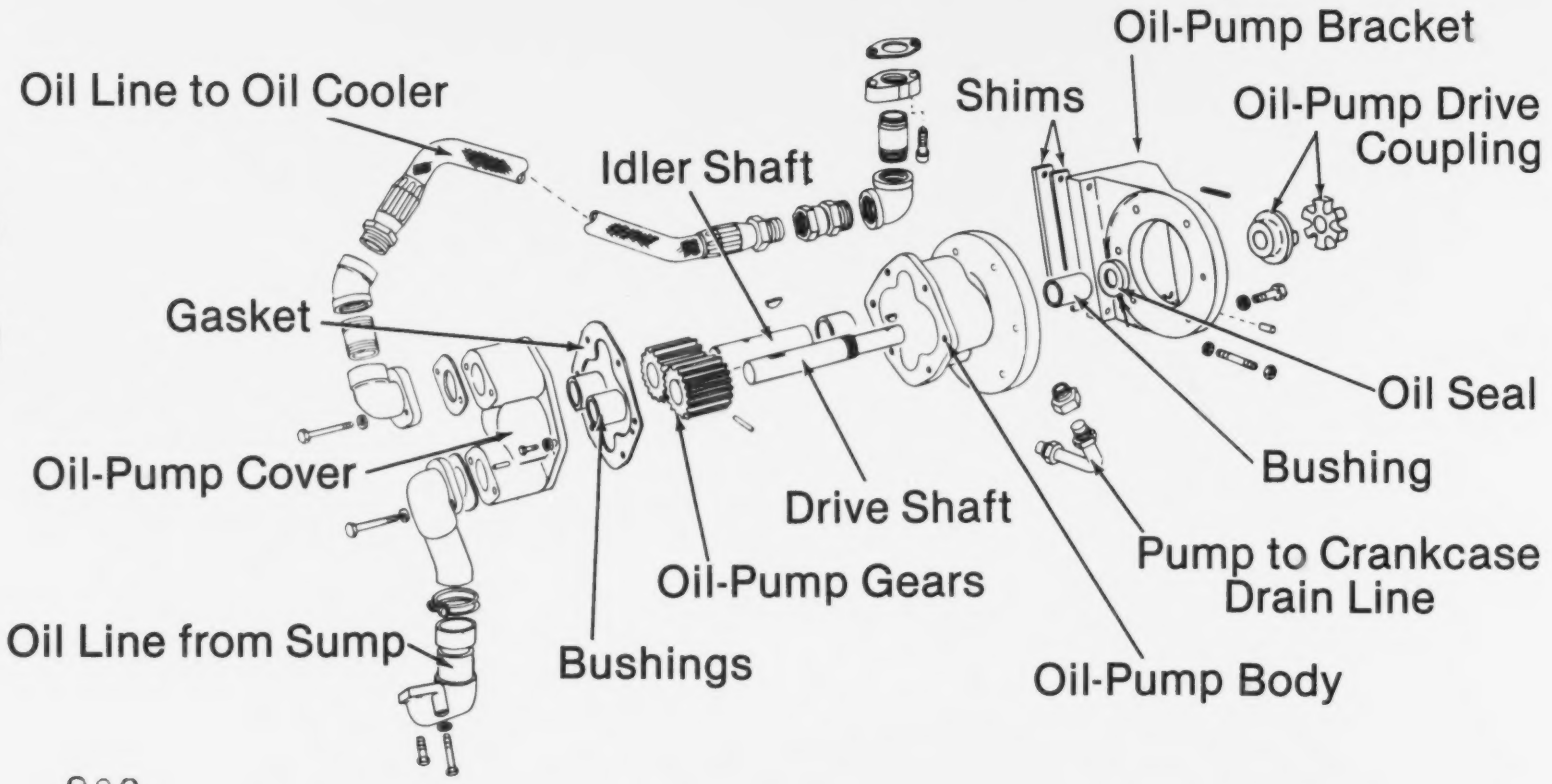






Types of Oil Pumps
(Continued)

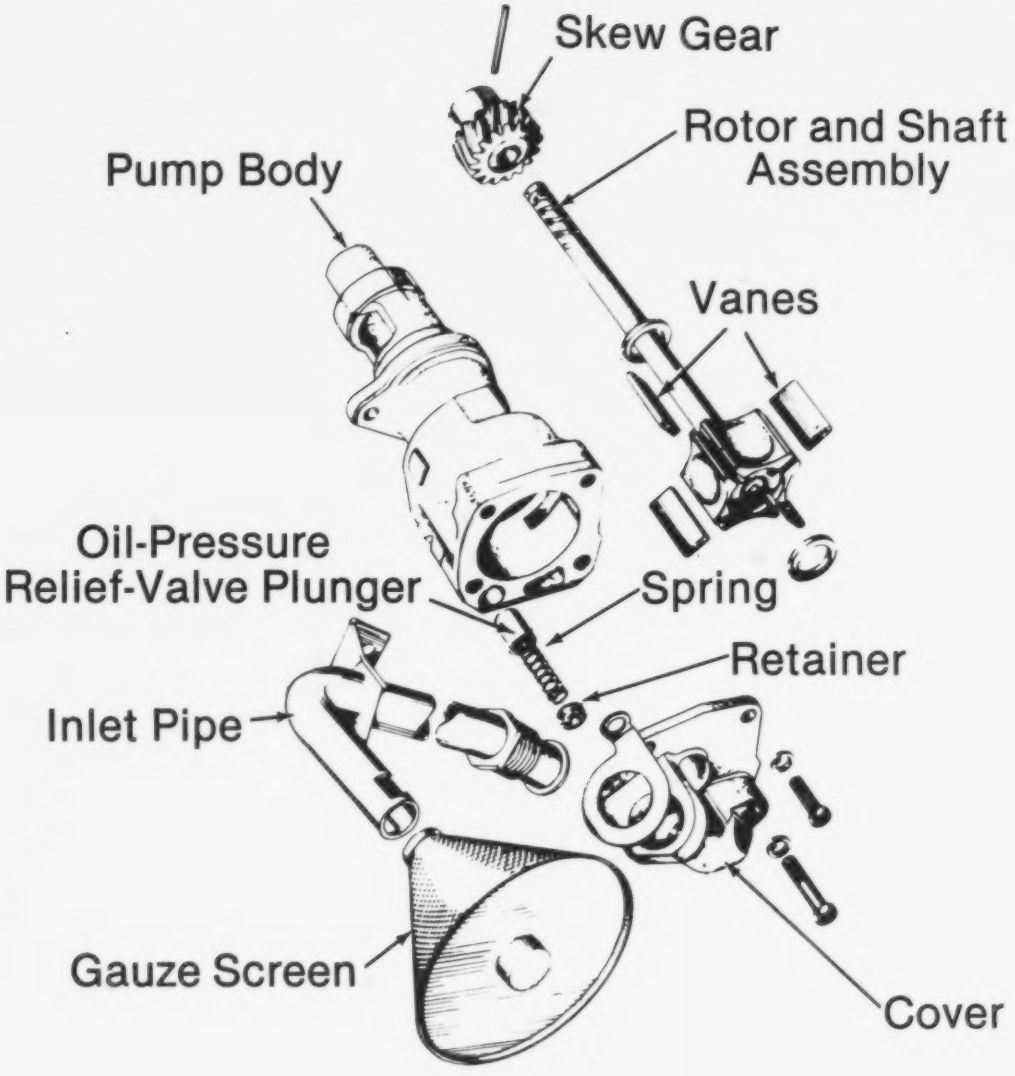
Exploded View of Gear-Type Oil Pump



Types of Oil Pumps

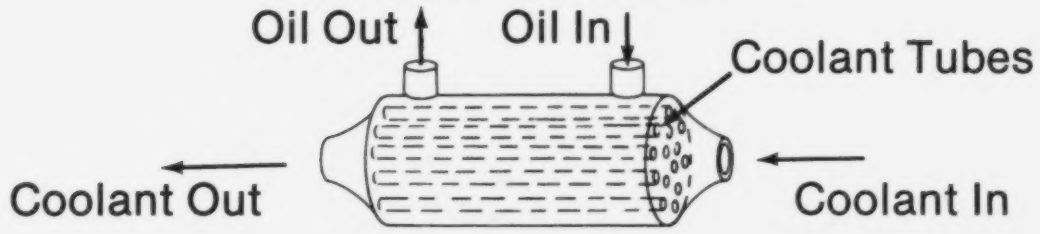
(Continued)

Vane-Type Oil Pump

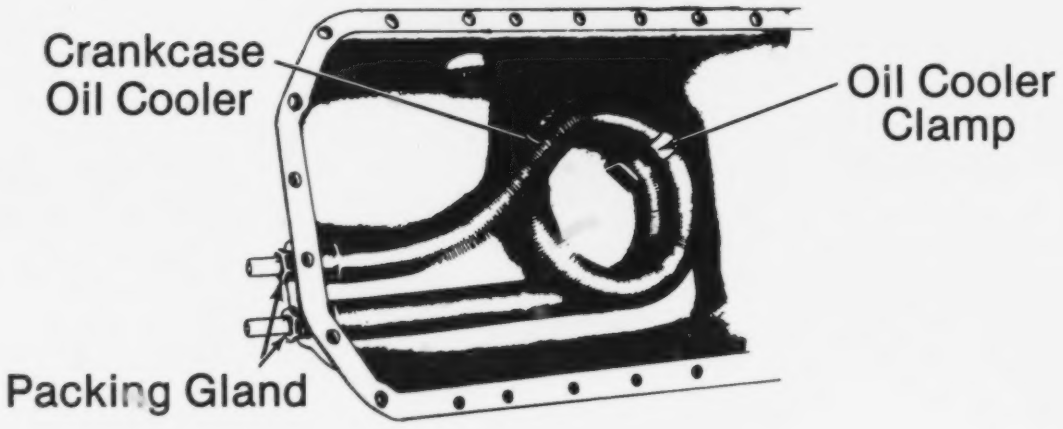


Oil Coolers

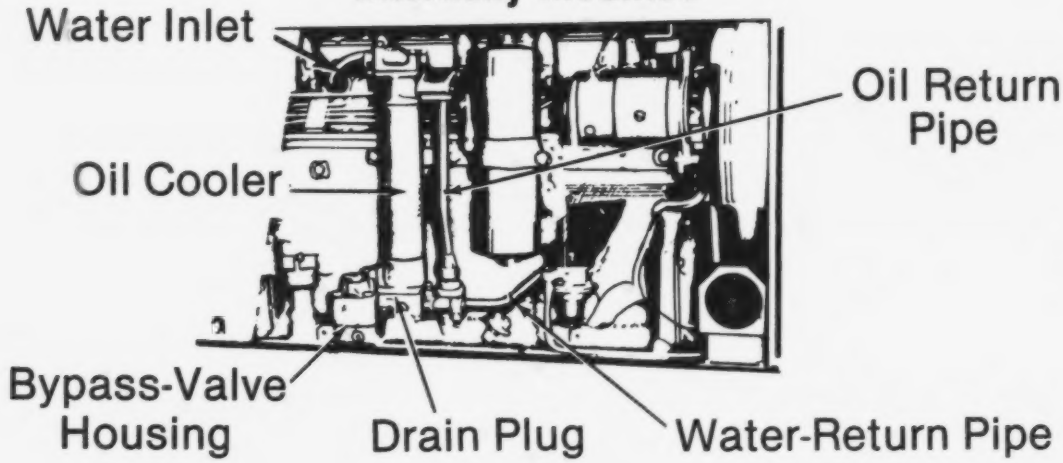
Operation of Engine Oil Cooler



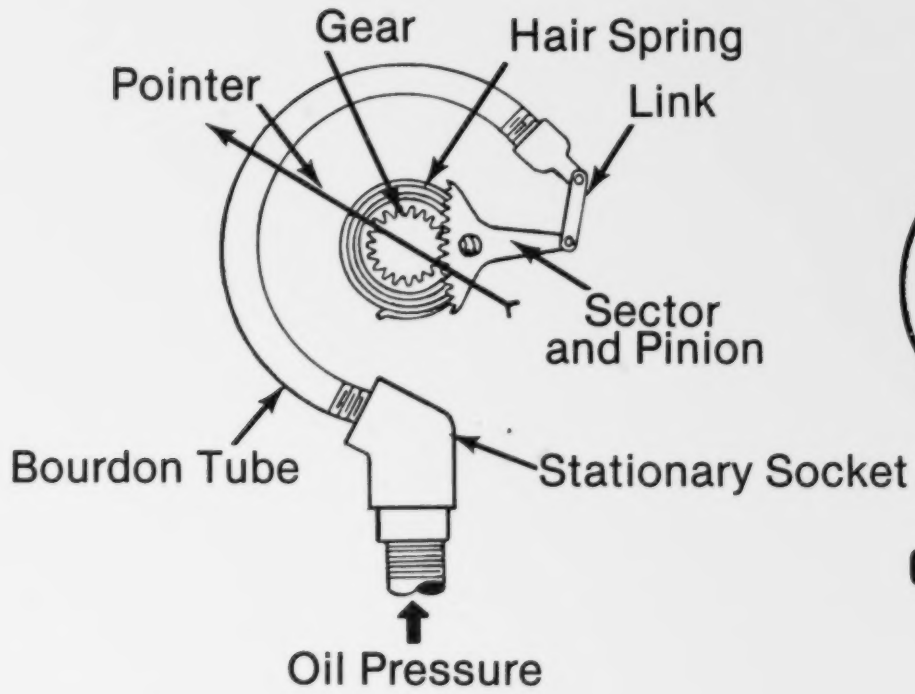
Externally Mounted



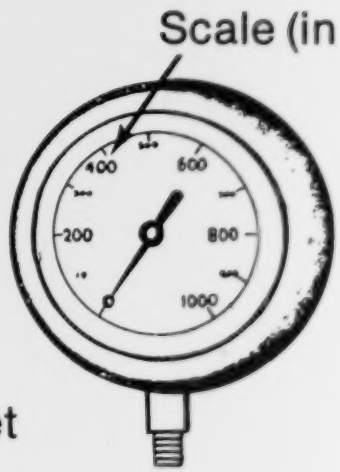
Internally Mounted



Oil-Pressure Indication Systems: Mechanical



Bourdon Tube Oil Gauge



Complete Gauge

813

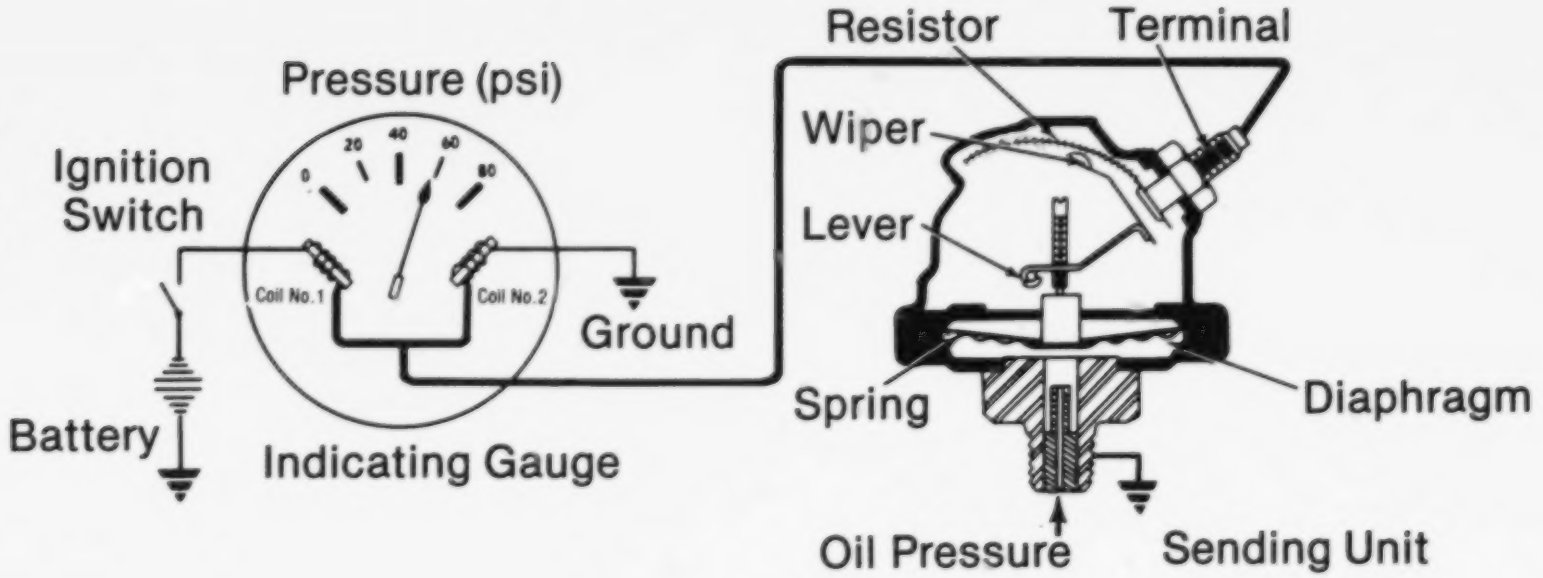
814

TM #9

HEM - 27-C

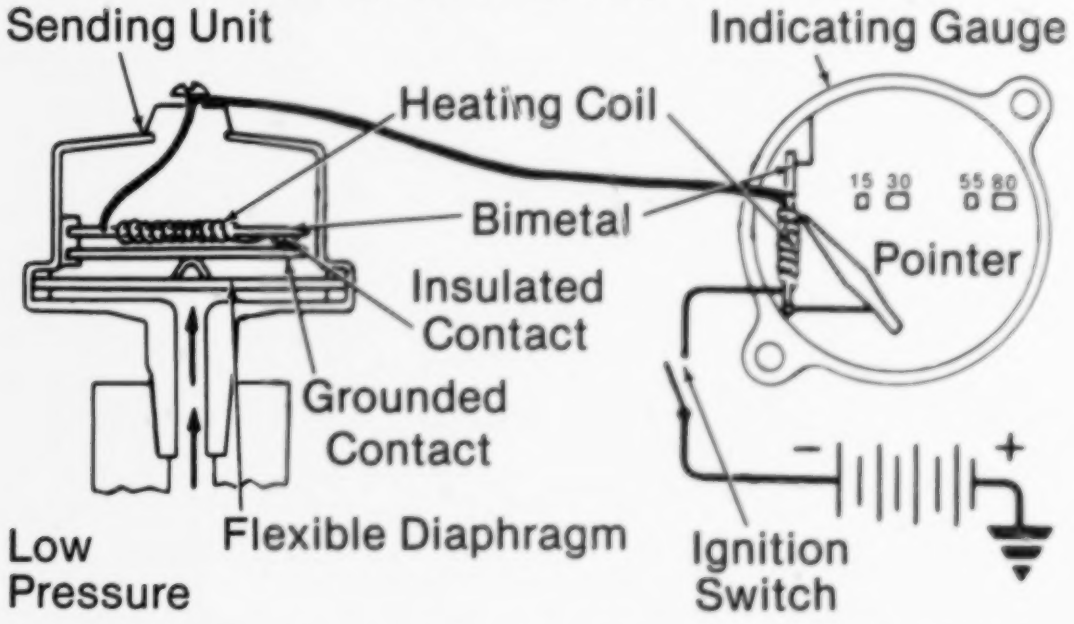
Oil-Pressure Indication Systems: Electrical

Electromagnetic-Coil System for Indicating Oil Pressure

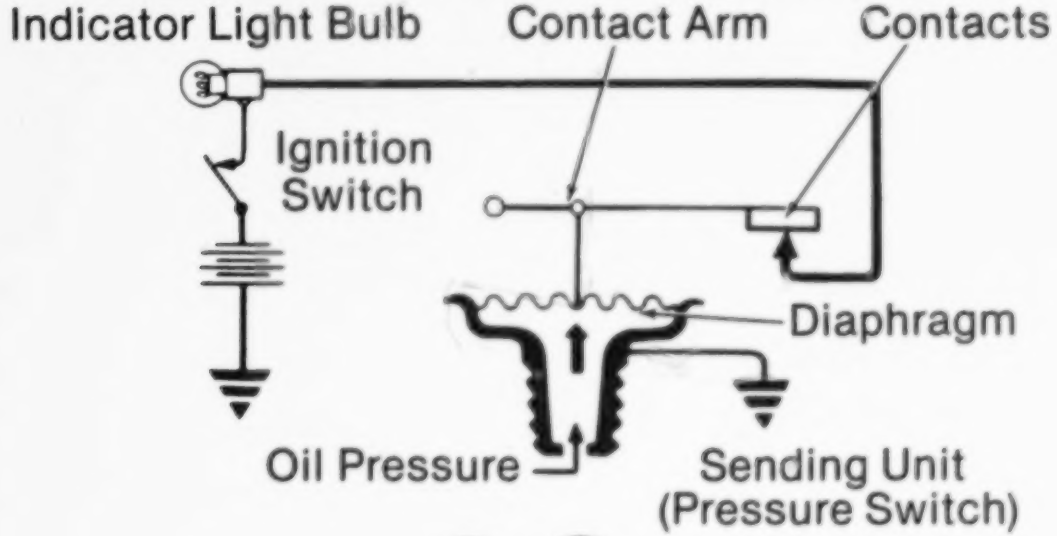


Oil-Pressure Indication Systems: Electrical
(Continued)

Operation with Low Oil Pressure
Heating Coil System for Indicating Oil Pressure



Pressure-Switch System for Indicating Oil Pressure



LUBRICATION SYSTEMS
UNIT I

JOB SHEET #1 — CHANGE OIL IN AN ENGINE

I. Equipment and materials

A. Drain pan

B. Wrench suitable for drain-plug removal

C. Jack

D. 4 jack stands

E. Oil spout

F. Shop towels

G. Service sticker

H. Service chart

I. Oil recommended by manufacturer

J. Appropriate service manual

II. Procedure

(CAUTION: Never get under an improperly supported vehicle.)

A. Support vehicle on jack stands if required

B. Position drain pan under engine drain plug

C. Remove drain plug

(CAUTION: Use care to avoid being burned by hot oil.)

D. Allow oil sufficient time to drain

(NOTE: Observe oil condition and color that might make further service necessary.)

E. Replace oil filter if required

(NOTE: Take filter apart and inspect for metal particles and other debris.)

F. Replace drain plug

(NOTE: Make sure that the gasket, if used, is in place and that the drain plug is securely tightened.)

JOB SHEET #1

G. Remove jack stands and lower vehicle to ground

H. Open engine compartment

I. Wipe dirt and grease away from oil filler cap

J. Remove oil filler cap

K. Refill crankcase to recommended level with the proper motor oil

(NOTE: Make sure that the tops of the oil cans and the filling spout are clean.)

L. Clean and reinstall oil filler cap

M. Start engine and operate it for a few minutes at low revolutions per minute

N. Check for oil leaks

O. Shut off engine

P. Check oil level on dipstick

(NOTE: Add oil as required in service manual. Do not overfill.)

Q. Fill out service chart

(NOTE: Make sure that date, hour, meter reading, and type of oil are included on service chart.)

R. Clean work area; clean and put away all tools and equipment

LUBRICATION SYSTEMS
UNIT I

JOB SHEET #2 — CHANGE AN OIL FILTER

I. Equipment and materials

- A. New filter gasket and element
- B. Shop towels
- C. Container to catch waste oil
- D. Suitable wrenches to remove filter
- E. Suction gun
- F. Jack
- G. 4 jack stands
- H. Service chart
- I. Service sticker
- J. Appropriate service manual

II. Procedure for replaceable-element-type oil filter on upper part of engine

- A. Clean dirt from filter cover
- B. Remove oil-filter cover (Figure 7)

FIGURE 7

JOB SHEET #2

C. Remove oil-filter element

(NOTE: Take filter apart and inspect for metal particles and other debris.)

D. Remove remaining oil from filter housing by removing drain plug from housing, or use suction gun to draw out the oil

E. Clean filter cover and housing

F. Remove old filter gasket

G. Install new filter gasket into filter cover

(NOTE: Install other small rubber gaskets as required.)

H. Install new filter element

I. Install filter cover

(NOTE: Make sure that gasket is in place.)

J. Tighten filter cover securely

K. Add oil or refill crankcase as required

L. Start engine

M. Check for leaks

N. Shut off engine

O. Check oil level on dipstick

(NOTE: Add oil as required. Do not overfill.)

P. Fill out service chart; indicate mileage and date that oil filter was changed

Q. Clean work area; clean and put away all tools and equipment

III. Procedure for replaceable-element-type oil filter on lower part of engine

A. Support front of vehicle on jack stands if required

(CAUTION: Never get under an improperly supported vehicle.)

B. Position drain pan under oil filter

C. Remove oil-filter housing bolt

JOB SHEET #2

D. Remove oil-filter housing

E. Remove oil-filter element from filter housing (Figure 8)

FIGURE 8

F. Clean the filter housing

G. Remove old oil-filter-housing gasket

H. Install new oil-filter-housing gasket

(NOTE: Make sure that new gasket is placed correctly.)

I. Install new oil-filter elements in filter housing

JOB SHEET #2

J. Install oil-filter housing and tighten bolt securely

K. Remove jack stands and lower vehicle to ground

L. Add oil or refill crankcase if required

M. Start engine

N. Check for leaks

O. Shut off engine

P. Check oil level on dipstick

(NOTE: Add oil if required. Do not overfill.)

Q. Fill out service chart; indicate hour, meter reading, and date that oil filter was changed

R. Clean work area; clean and put away all tools and equipment

IV. Procedure for sealed-cartridge-type oil filter

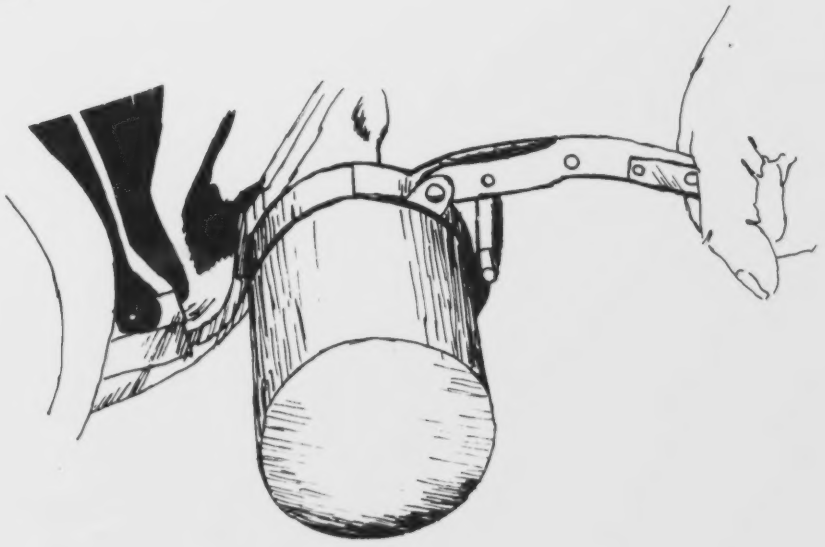
A. Support front of vehicle on jack stands if required

B. Place drain pan under oil filter

C. Remove oil-filter cartridge with suitable tool (Figure 9)

(NOTE: Turn counterclockwise to remove.)

FIGURE 9



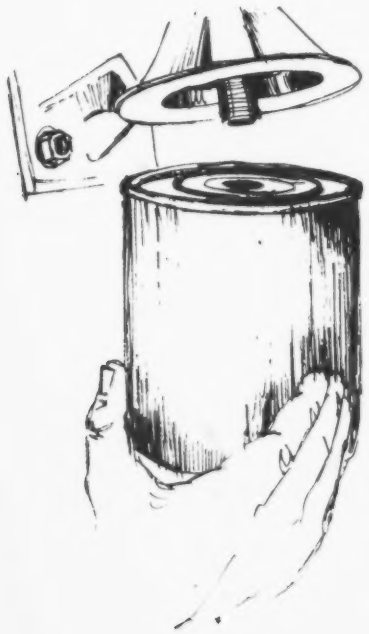
JOB SHEET #2

D. Lubricate sealing gasket on new oil-filter cartridge with clean motor oil if required

E. Install new oil-filter cartridge; tighten to manufacturer's recommendation (Figure 10)

(NOTE: Usually hand tightening is sufficient.)

FIGURE 10



F. Remove jack stands and lower vehicle to ground

G. Add oil or refill crankcase as required

H. Start engine

I. Check for leaks

J. Shut off engine

K. Check oil level on dipstick

(NOTE: Add oil if required. Do not overfill.)

L. Fill out service chart; indicate hour, meter reading, and date that oil filter was changed

M. Clean work area; clean and put away all tools and equipment

LUBRICATION SYSTEMS
UNIT I

JOB SHEET #3 — CHECK AND ADJUST OIL PRESSURE
ON A LIVE ENGINE

I. Equipment and materials

A. Screwdriver

B. Master pressure gauge

C. End wrench

D. Shop towel

E. Shim stock for regulating valve

F. Safety glasses

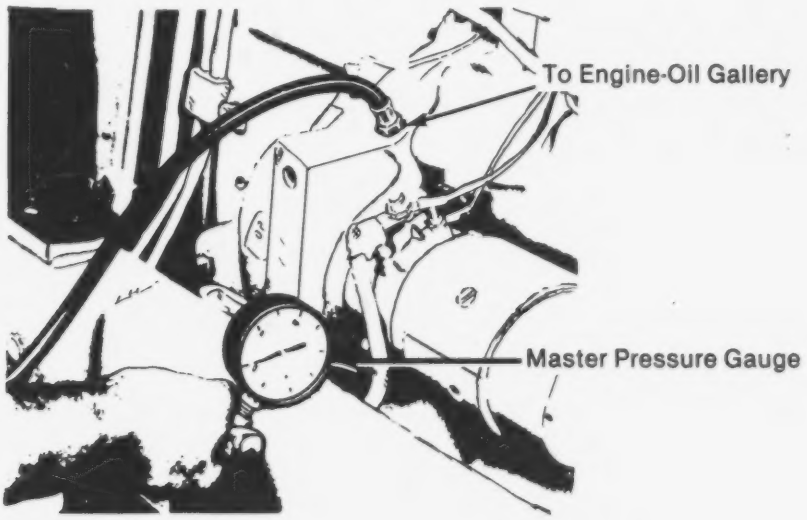
G. Appropriate service manual

II. Procedure

A. Check condition of oil filter; replace filter if dirty

B. Install a master gauge (Figure 11)

FIGURE 11



C. Start engine and warm up at fast idle speed

D. Record pressure reading from gauge

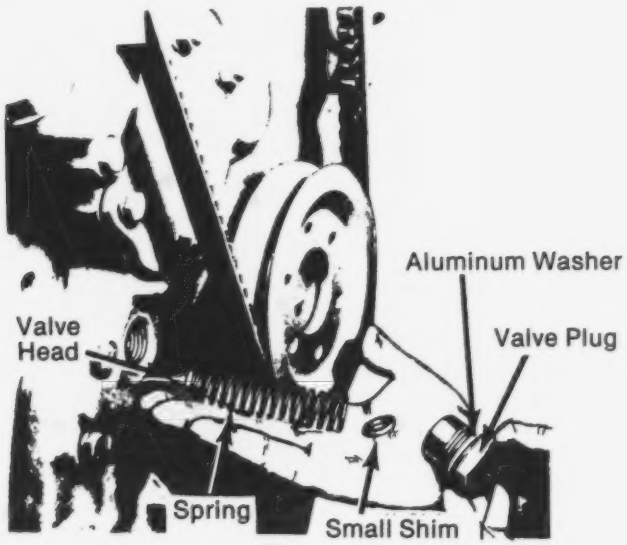
E. Compare reading with engine specifications

JOB SHEET #3

F. Adjust pressure-regulating valve

1. Adjust pressure-regulating valve with shims (Figure 12)

FIGURE 12

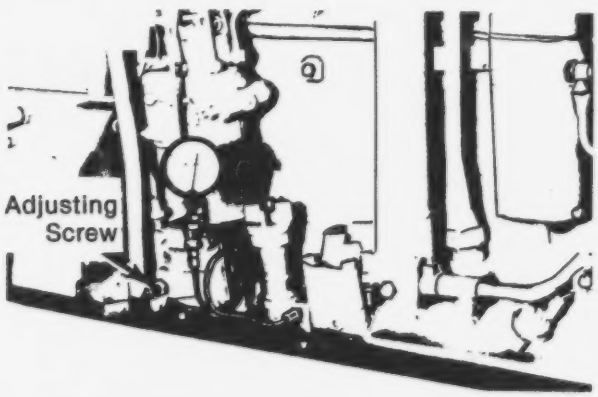


a. Raise pressure by adding shims

b. Lower pressure by removing shims

2. Adjust pressure-regulating valve with screw (Figure 13)

FIGURE 13



a. Raise pressure by turning screw in

b. Lower pressure by turning screw out

G. Clean work area; clean and put away all tools and equipment

LUBRICATION SYSTEMS
UNIT I

TEST

NAME _____ SCORE _____

1. Match to their correct definitions terms associated with lubrication systems. Write the correct numbers in the blanks.

_____a.	Substance that reduces friction between surfaces	1. Viscosity index
_____b.	Material added to coolant to prevent freezing	2. Sludge
_____c.	Measure of the ability of an oil to resist changes in viscosity when heated	3. Lubricant
_____d.	Measure of the ability of an oil to meet the low-temperature requirements of a light oil and the high-temperature requirements of a heavy oil	4. Antifreeze
_____e.	Muddy or slushy deposit or sediment	5. Viscosity
_____f.	Resistance to movement between any two objects placed in contact with each other	6. Multiviscosity
_____g.	Measure of the ability of an oil to resist flowing	7. Friction

2. List four purposes of the lubrication system.

a. _____

b. _____

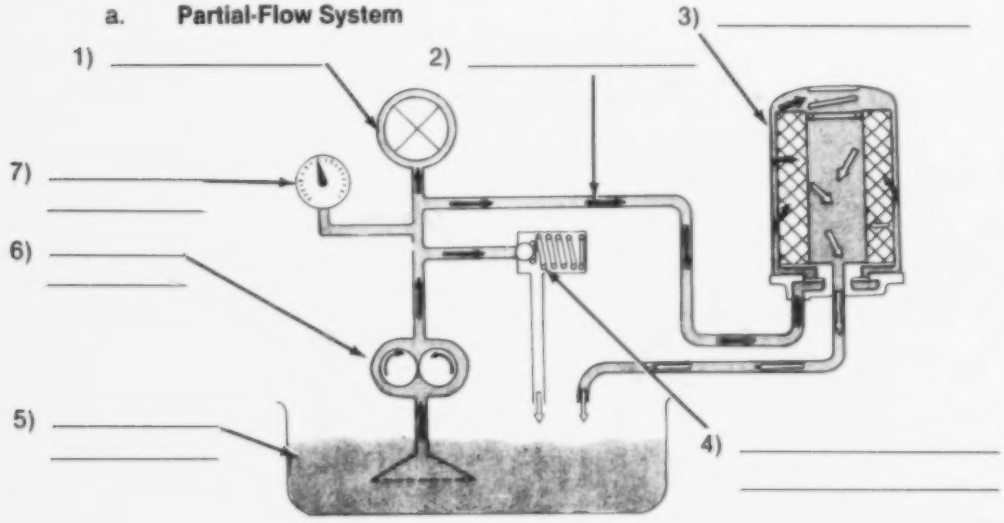
c. _____

d. _____

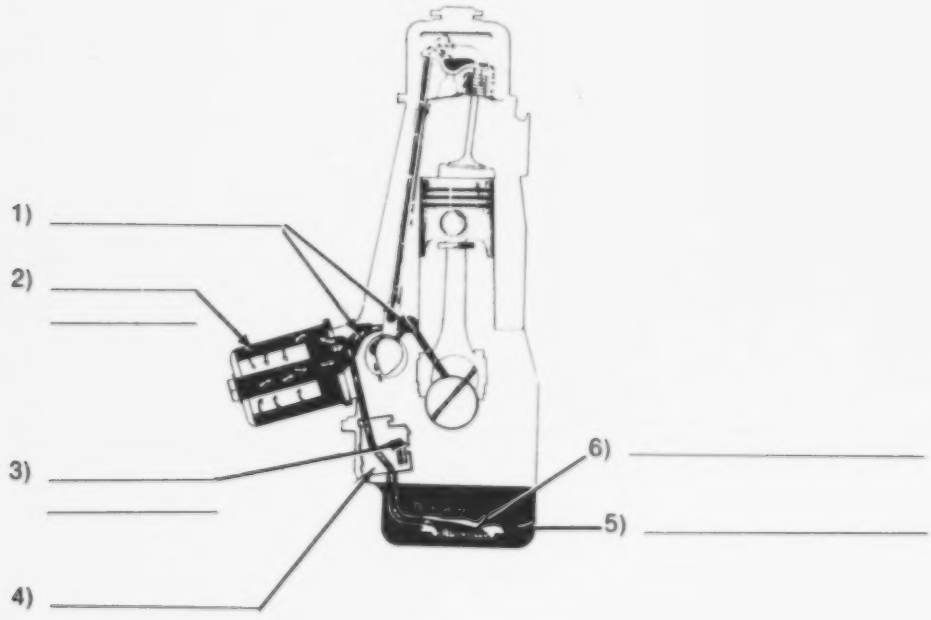
TEST

3. Label components of the engine lubrication systems illustrated below.

a. **Partial-Flow System**



b. **Full-Flow System**



TEST

4. Match components of the engine lubrication system to their correct purposes. Write the correct numbers in the blanks.

_____a.	Carrying engine oil from one area to another	1. Oil-pressure relief valve or regulating valve
_____b.	Straining engine oil to remove abrasive particles	2. Pressure gauge
_____c.	Limiting maximum oil pressure	3. Oil pump
_____d.	Forcing oil under pressure to various parts of engine	4. Oil pickup
_____e.	Allowing pump to pick up oil from oil pan	5. Oil galleries
_____f.	Providing reservoir for engine oil	6. Oil pan
_____g.	Indicating oil pressure during engine operation	7. Oil filter

5. List types of lubrication systems.

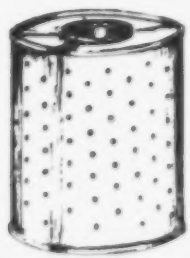
a. _____

b. _____

c. _____

6. Identify the following types of oil filters. Write the correct names in the blanks.

Sealed cartridge
Replaceable element

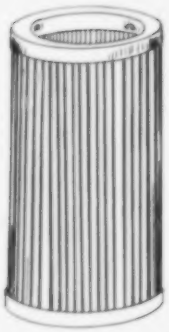


Surface filter, wire mesh-type
Depth filter, cotton waste-type

a. _____ b. _____

_____ _____

TEST



c. _____ d. _____

_____ _____

7. List types of oil pumps.

a. _____

b. _____

c. _____

8. State guidelines to consider when selecting engine oil.

a. _____

_____

b. _____

_____

c. _____

_____

TEST

9. Match engine-oil additives to their correct functions. Write the correct numbers in the blanks.

_____a.	Prevents wax particles in oil from getting too thick in cold temperatures or too thin in hot temperatures	1. Pour-point depressant
_____b.	Protects oil molecules from combining with oxygen, thus stops formation of acid, varnish, and sludge	2. Viscosity-index improver
_____c.	Prevents formation in oil of air bubbles that would restrict lubrication	3. Anticorrosion
_____d.	Clings to metal surfaces and repels water droplets to prevent rusting while engine is not in operation	4. Detergent dispersant
_____e.	Suspends particles of contaminants in oil to keep metal surfaces clean and to prevent deposit formation	5. Oxidation inhibitor
_____f.	Ensures lubrication where extreme pressures are encountered	6. Foam inhibitor
_____g.	Helps oil give top lubricating protection at both high and low temperatures by giving the oil the beneficial properties of both light and heavy oils	7. Antirust
_____h.	Protects bearings and other metal surfaces from corrosion by acids created by combustion gases in crankcase	8. Extreme pressure

10. Select from the following list sources of oil contamination. Write an "X" in the blank before each correct answer.

_____a. Improper engine warm-up

_____b. Carbon particles

_____c. Foam inhibitor in the oil

_____d. Fuel dilution

_____e. Engine wear

_____f. Antifreeze leaking into oil supply

TEST

_____g. Oxidation

_____h. Storage and handling

_____i. Oil additives

_____j. Dust in air breathed into engine

11. Describe circulation of water and oil in an oil cooler.

a. Internally mounted — _____

_____

b. Externally mounted — _____

_____

12. Describe types of oil-pressure indication systems.

a. Mechanical — _____

_____

b. Electrical — _____

_____

(NOTE: Test question 13 lists the job sheets. They are an important part of this test. If they have not been completed, check with your instructor.)

13. Demonstrate the ability to

a. Change oil in an engine.

b. Change an oil filter.

c. Check and adjust oil pressure on a live engine.

LUBRICATION SYSTEMS
UNIT I

ANSWERS TO TEST

1. a. 3 e. 2
   b. 4 f. 7
   c. 1 g. 5
   d. 6

2. Answer should include any four of the following
   a. Lubricating moving parts to minimize friction
   b. Acting as cooling agent to dissipate heat from engine parts
   c. Forming a seal between piston rings and cylinder walls
   d. Cleaning and flushing moving parts
   e. Absorbing shock between bearings and other parts
   f. Deadening engine noise

3. a. Partial-flow system
   1) Engine bearings
   2) Oil galleries
   3) Oil filter
   4) Pressure-regulating valve
   5) Oil pan
   6) Oil pump
   7) Pressure gauge

   b. Full-flow system
   1) Oil galleries
   2) Oil filter
   3) Oil-pressure relief valve
   4) Oil pump
   5) Oil pan
   6) Oil pickup

4. a. 5 e. 4
   b. 7 f. 6
   c. 1 g. 2
   d. 3

ANSWERS TO TEST

5. a. Circulating splash
   b. Internal force-feed and splash
   c. Full internal force-feed

6. a. Replaceable element
   b. Depth filter, cotton waste-type
   c. Surface filter, wire mesh-type
   d. Sealed cartridge

7. a. Gear
   b. Rotor
   c. Vane

8. a. Use oil of the proper viscosity for average temperature at which vehicle will operate
   b. Use oil of the proper service rating as recommended by manufacturer
   c. Select oils that have been service tested

9.

a.	1	e.	4
b.	5	f.	8
c.	6	g.	2
d.	7	h.	3

10. a, b, d, e, f, g, h, j

11. Description should include the following
    a. Internally mounted — Engine coolant is pumped through oil cooler mounted in crankcase, then back to radiator where heat is dissipated
    b. Externally mounted — Both water and oil are pumped through oil cooler

ANSWERS TO TEST

12. Description should include the following

    a. Mechanical — Bourdon tube gauge; tube straightens when pressure is applied

    b. Electrical — Sending unit is at pressure source; indicating gauge is on control panel

13. Performance skills evaluated to the satisfaction of the instructor

AIR-INTAKE AND EXHAUST SYSTEMS
UNIT II

UNIT OBJECTIVE

After completing this unit, the student should be able to identify components of air-intake and exhaust systems, remove and replace components of the exhaust system, and disassemble and assemble a supercharger and turbocharger. The student will show this knowledge by completing the job sheets and unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match to their correct definitions terms associated with exhaust systems.
2. List parts of an air-intake system.
3. Discuss types of air cleaners.
4. State the purpose of the exhaust system.
5. Identify components of the exhaust system.
6. Describe operation of the manifold heat-control valve.
7. Distinguish between internal and external causes of exhaust system corrosion.
8. Label basic components of the exhaust-gas recirculating system.
9. State the purpose of the exhaust-gas recirculating system.
10. Discuss methods of scavenging the cylinders on a two-stroke-cycle engine.
11. Distinguish between port and valve scavenging on a two-stroke-cycle engine.
12. Distinguish between types of superchargers.
13. Select form a list advantages of a turbocharged engine.
14. List safety precautions pertaining to exhaust systems.
15. Demonstrate the ability to
    a. Test an engine for air-flow restrictions.
    b. Service a manifold heat-control valve.

OBJECTIVE SHEET

c. Remove and replace an exhaust manifold.

d. Remove and replace an exhaust pipe.

e. Remove and replace a muffler.

f. Inspect a turbocharger for satisfactory operation.

g. Remove, disassemble, service, assemble, and install a turbocharger.

h. Disassemble, service, repair, and assemble a supercharger.

AIR-INTAKE AND EXHAUST SYSTEMS
UNIT II

SUGGESTED ACTIVITIES

I. Suggested activities

A. Order films and other materials planned to supplement unit.

(NOTE: Engine manufacturers are excellent sources for slide and film presentations on exhaust systems. Write directly to the appropriate company or manufacturer. Check with major engine manufacturers and equipment dealers for visual aids that demonstrate exhaust-system operation.)

B. Gather equipment and materials needed for job sheet demonstrations.

C. Obtain transparencies.

(NOTE: Transparencies are available from AGC and CIMC.)

D. Provide students with objective sheet.

E. Discuss unit and specific objectives.

F. Provide students with information and job sheets.

G. Discuss information sheet.

H. Demonstrate and discuss procedures outlined in job sheets.

I. Give test.

J. Complete appropriate section of competency profiles.

(NOTE: Competency profiles are available from AGC and CIMC.)

II. Instructional materials

A. Objective sheet

B. Suggested activities

C. Information sheet

D. Transparency masters

1. TM #1 — Dry-Element-Type Air Cleaner

2. TM #2 — Viscous-Impingement-Type Air Cleaner

SUGGESTED ACTIVITIES

3. TM #3 — Oil-Bath-Type Air Cleaner
4. TM #4 — Intake and Exhaust System Components
5. TM #5 — Operation of Manifold Heat-Control Valve
6. TM #6 — Exhaust-Gas Recirculating System
7. TM #7 — Crankcase-Scavenging Engine
8. TM #8 — Scavenging Pump
9. TM #9 — Blower
10. TM #10 — Port-Scavenging Engine
11. TM #11 — Valve-Scavenging Engine
12. TM #12 — Positive Displacement Supercharger
13. TM #13 — Centrifugal-Type Supercharger

E. Job sheets

1. Job Sheet #1 — Test an Engine for Air-Flow Restrictions
2. Job Sheet #2 — Service a Manifold Heat-Control Valve
3. Job Sheet #3 — Remove and Replace an Exhaust Manifold
4. Job Sheet #4 — Remove and Replace an Exhaust Pipe
5. Job Sheet #5 — Remove and Replace a Muffler
6. Job Sheet #6 — Inspect a Turbocharger for Satisfactory Operation
7. Job Sheet #7 — Remove, Disassemble, Service, Assemble, and Install a Turbocharger
8. Job Sheet #8 — Disassemble, Service, Repair, and Assemble a Supercharger

F. Test

G. Answers to test

SUGGESTED ACTIVITIES

III. Unit references

A. Armstrong, Ivan J. *Auto Mechanics,* Vol. I. Stillwater, Oklahoma: State Department of Vocational and Technical Education/Curriculum and Instructional Materials Center, 1976.

B. Foutes, William A. *Diesel Engine Mechanics.* Stillwater, Oklahoma: Mid-America Vocational Curriculum Consortium, Inc., 1977.

C. Foutes, William A. *Diesel Mechanics: Fundamentals*. Stillwater, Oklahoma: Mid-America Vocational Curriculum Consortium, Inc., 1982.

AIR-INTAKE AND EXHAUST SYSTEMS
UNIT II

INFORMATION SHEET

I. Terms and definitions

A. Blower — Device for increasing air pressure and velocity

B. Catalyst — Material that when present increases the rate of chemical reaction in exhaust gases

C. Crossover pipe — Pipe used on V-type engines to connect exhaust manifolds entering a single exhaust pipe

D. Exhaust manifold — Pipe connecting engine exhaust ports to exhaust pipe; usually made of cast iron

E. Exhaust pipe — Pipe connecting exhaust manifold to muffler

F. Filter — Unit containing a material of varying degrees of fineness to trap foreign particles

G. Manifold heat-control valve — Valve located in exhaust manifold; deflects a certain amount of hot gas around carburetor base to aid engine warm-up

H. Muffler — Chamber through which exhaust gases are passed to quiet the sounds of the engine

I. Naturally aspirated — Not supercharged

J. Pipe clamp — Circular bolt used to clamp exhaust pipe to muffler

K. Pipe hanger — Metal and fabric strap used to support the exhaust system

L. Precleaner — Device that collects some dirt from the air before air enters main air cleaner

M. Scavenging — Method of pushing air out of cylinders during exhaust stroke on two-cycle engines

N. Supercharging — Method of charging cylinders on the intake stroke with fresh air above atmospheric pressure

O. Turbocharger — Exhaust-driven turbine that drives a centrifugal compressor

P. Valve — Device for sealing cylinder-head intake or exhaust ports

II. Parts of an air-intake system

A. Precleaner, air cleaner

B. Supercharger (where applicable)

INFORMATION SHEET

C. Intake manifold

D. Piping

E. Intake valves or ports

III. Types of air cleaners (Transparencies #1-#3)

A. Dry element — Cleans air by passing it through a maze of metal wool, wire, or screens

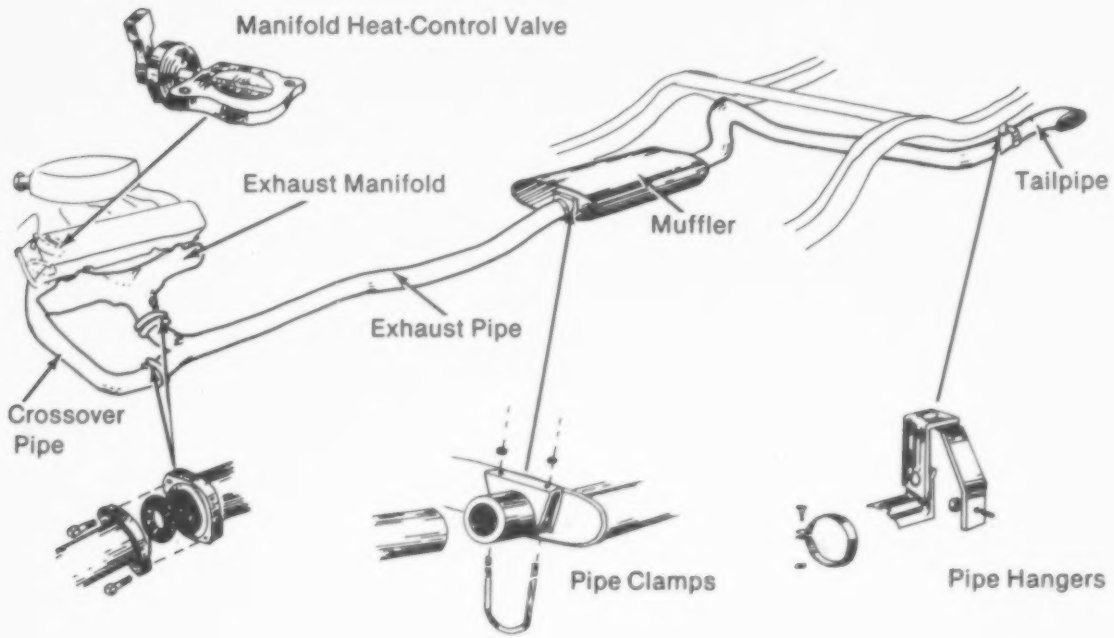
B. Viscous impingement — Cleans air by passing it through a maze of metal wool, wire, or screens saturated with oil

C. Wet (oil bath) — Cleans air by directing it through a center tube into an inner oil cup where direction of air flow is reversed, thus causing most of the dirt to become trapped by the oil and to settle in the sump

IV. Purpose of the exhaust system — To scavenge exhaust gases efficiently from the combustion chamber and conduct them to the outside air with a minimum of noise

V. Components of the exhaust system (Figure 1; Transparency #4)

FIGURE 1



INFORMATION SHEET

VI. Operation of the manifold heat-control valve (Transparency #5)

A. Engine cold — Heat-control valve is shut to allow exhaust gases to pass under carburetor base to bring about better fuel atomization and warm-up

B. Engine warm — Heat-control valve is open to allow exhaust gases to pass out to exhaust system

VII. Causes of exhaust system corrosion

A. Internal corrosion

1. Water caused by combustion process collects in muffler

2. Water mixing with exhaust gases creates a light acid that etches exhaust metal

(NOTE: Corrosion is extreme during short moves because the system does not get hot enough to evaporate the water.)

B. External corrosion

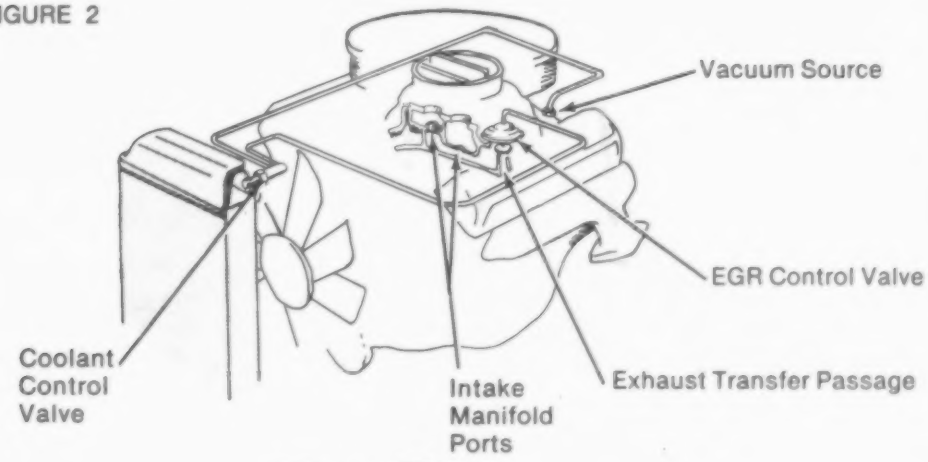
1. Rusting occurs due to rain, snow, and humidity

2. Corrosion is accelerated when equipment is in contact with salt, calcium, or lime

VIII. Basic components of the exhaust-gas recirculating system (Transparency #6; Figure 2)

(NOTE: An exhaust-gas recirculating system [EGR] may contain other components such as a vacuum amplifier, time-delay solenoid, coolant-control idle-enrichment valve, delay timer, and ported vacuum source.)

FIGURE 2



INFORMATION SHEET

IX. Purpose of the exhaust-gas recirculating system — To reduce oxides of nitrogen in engine exhaust gases by lowering peak flame temperature during combustion

(NOTE: Reduction is accomplished by allowing a predetermined amount of hot exhaust gas to recirculate and dilute the incoming fuel/air mixture.)

X. Methods of scavenging the cylinders on a two-stroke-cycle engine (Transparencies #7-#9)

A. Crankcase

1. Air enters engine through crankcase

2. Each downward movement of piston compresses vapor within crankcase until intake port or valve opens

3. Compressed vapor escapes into cylinder at a pressure nearly equal to atmospheric pressure

B. Power piston — Separate piston driven by engine crankshaft pushes vapor into cylinder as intake valve or port opens

C. Blower — Positive-displacement rotary blower driven by engine compresses vapor into air chamber surrounding intake ports

XI. Port and valve scavenging on a two-stroke-cycle engine (Transparencies #10 and #11)

A. Port scavenging — Air enters and gas leaves through ports in cylinder block or liner that piston uncovers

B. Valve scavenging — Air enters through ports in cylinder block, and gases leave through valves in cylinder head

(NOTE: The scavenging process in the two-cycle engine uses a swish of air to push out the spent gases and replace them with fresh air at atmospheric pressure.)

XII. Types of superchargers (Transparencies #12 and #13)

A. Positive displacement

(NOTE: The Roots-type blower is a positive-displacement supercharger.)

1. Driven by a chain, belt, or gear

2. Resembles oil pump in design

INFORMATION SHEET

B. Centrifugal

(NOTE: Turbochargers are exhaust-driven, centrifugal-type superchargers.)

1. Driven by engine, engine exhaust, or separate motor

2. Moves impeller thirty times engine speed

XIII. Advantages of a turbocharged engine

A. Increases horsepower output of a given displacement engine

B. Reduces weight by delivering more horsepower per pound than nonturbocharged engines

C. Costs less on a dollar-per-horsepower basis than nonturbocharged engines

D. Maintains horsepower at high altitudes

(NOTE: Naturally aspirated engines lose 3 percent of horsepower per each 1,000 feet of altitude.)

E. Reduces exhaust smoke by supplying excess air to reduce exhaust density

XIV. Safety precautions pertaining to exhaust systems

(CAUTION: Exhaust gases contain carbon monoxide, a deadly poison.)

A. Do not operate engines in a closed area without adequate ventilation

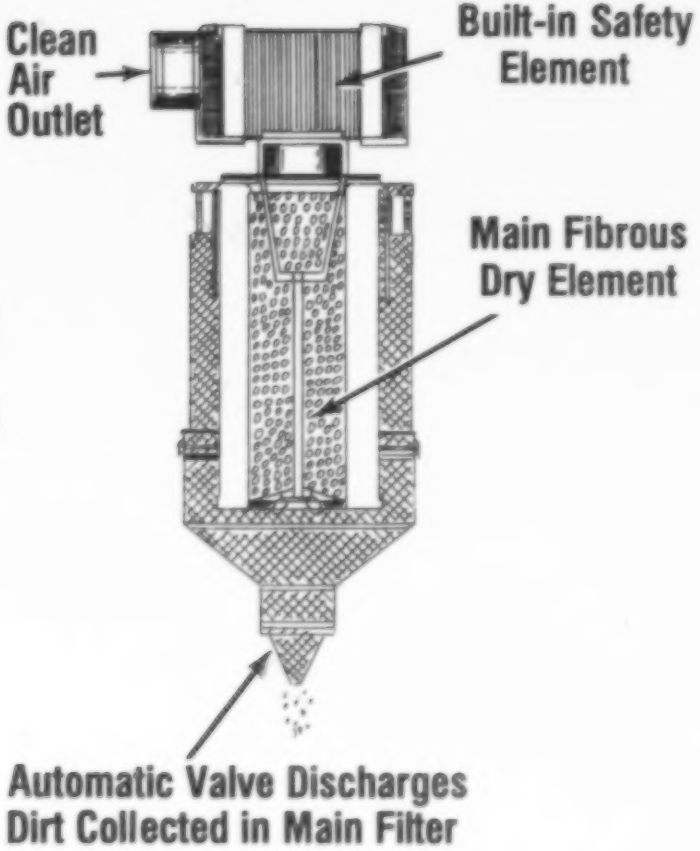
B. Repair leaks in exhaust system immediately

C. Do not operate equipment from a closed cab without adequate ventilation

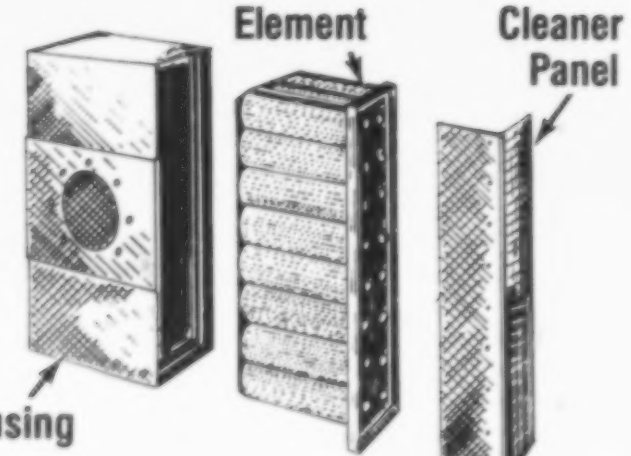
D. Do not touch any part of exhaust system when it is hot

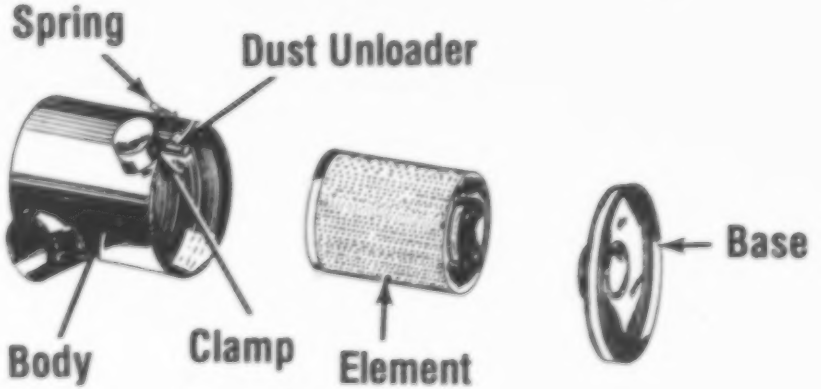
E. When operating an engine in the shop, use shop's exhaust-ventilation system

Dry-Element-Type Air Cleaner


Clean Air Outlet
Built-in Safety Element
Main Fibrous Dry Element
Automatic Valve Discharges Dirt Collected in Main Filter

846





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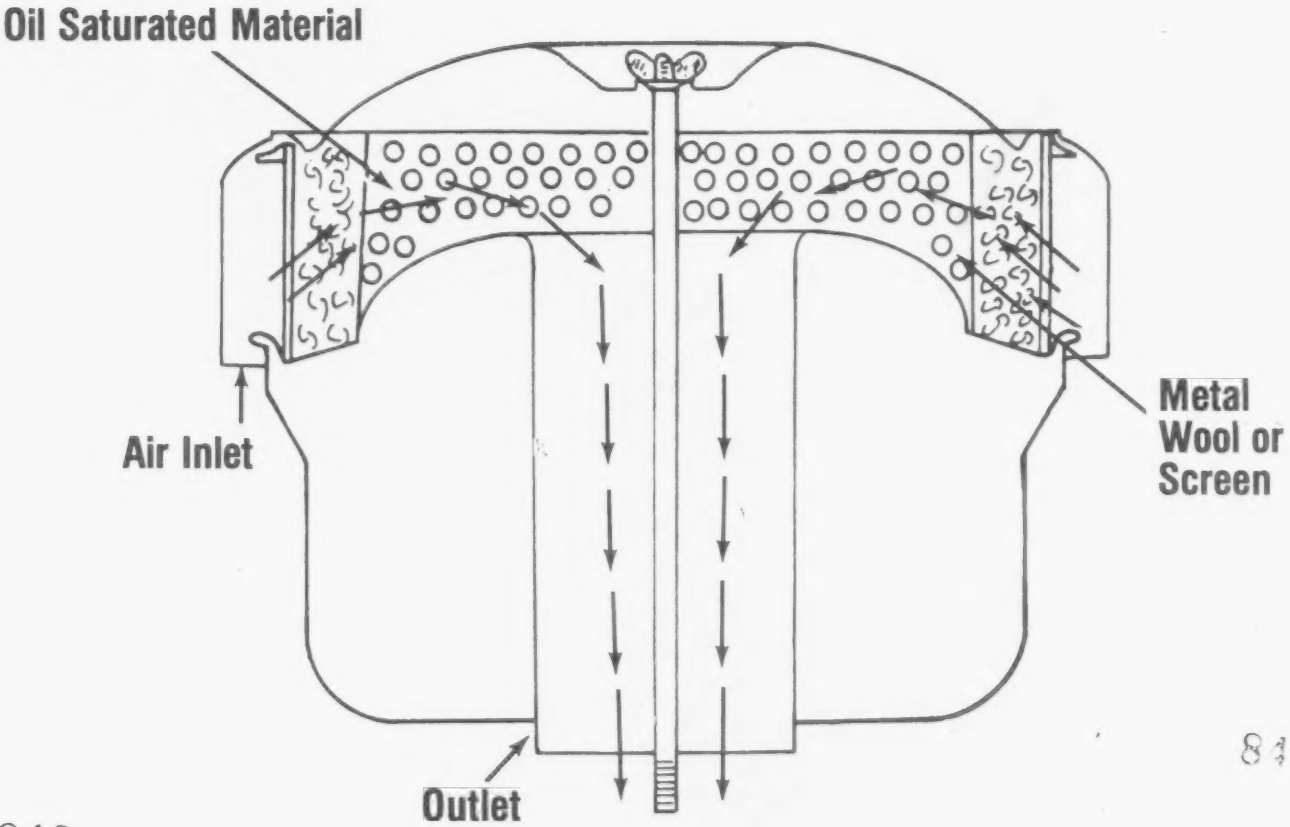
TM #1

HEM - 65-C

Viscous-Impingement-Type Air Cleaner



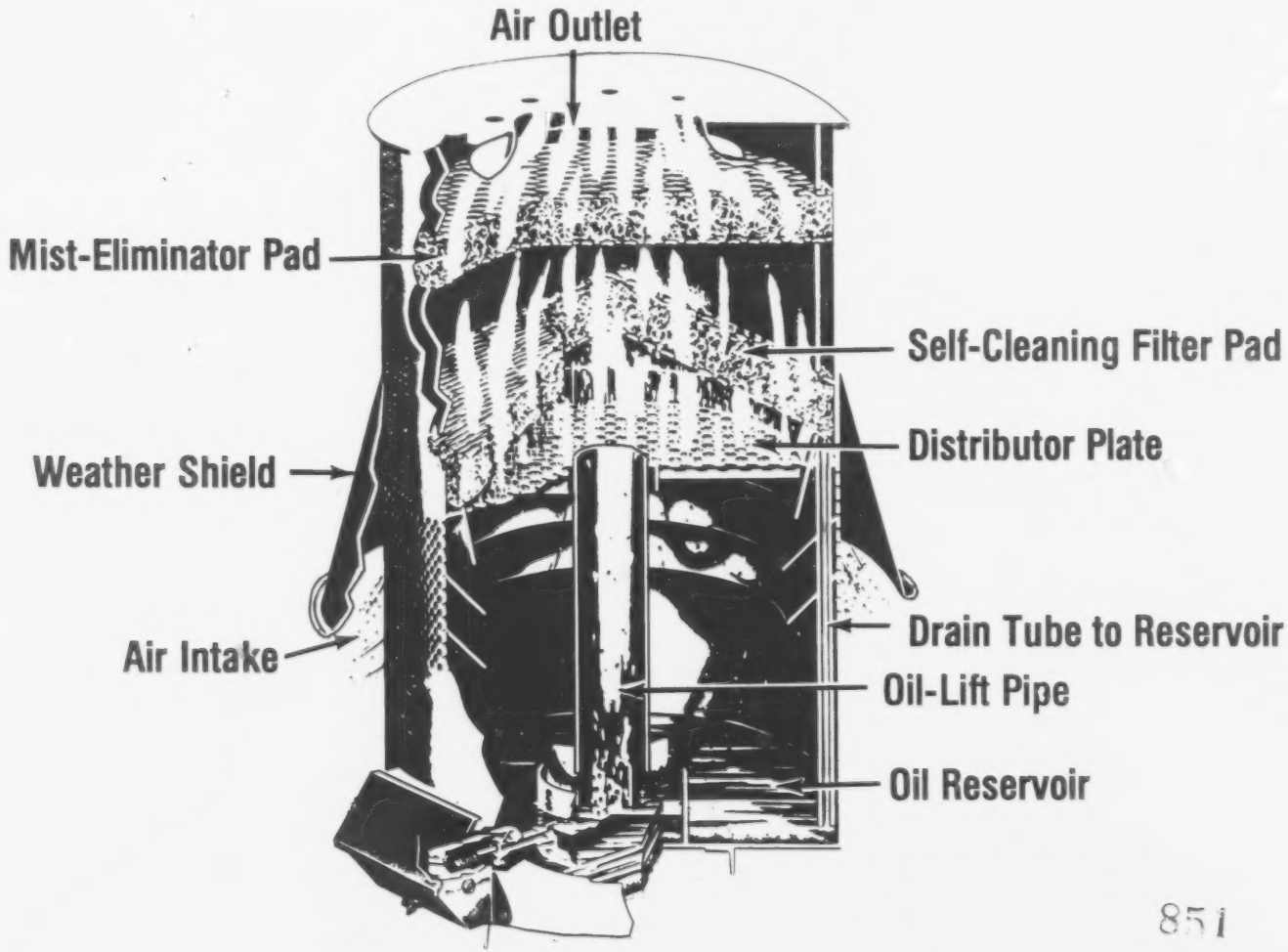
848

849

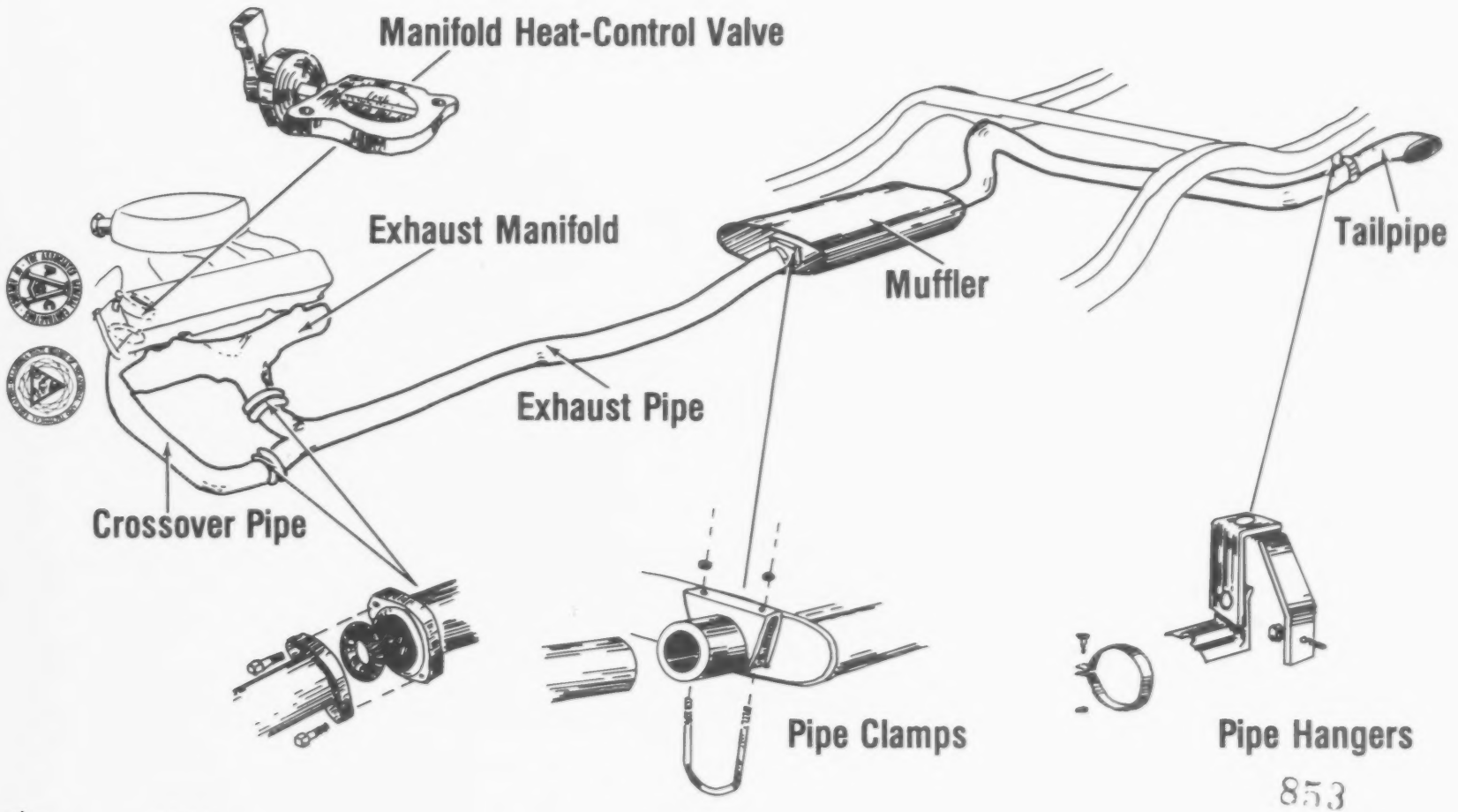
TM #2

HEM - 67-C

Oil-Bath-Type Air Cleaner



Intake and Exhaust System Components



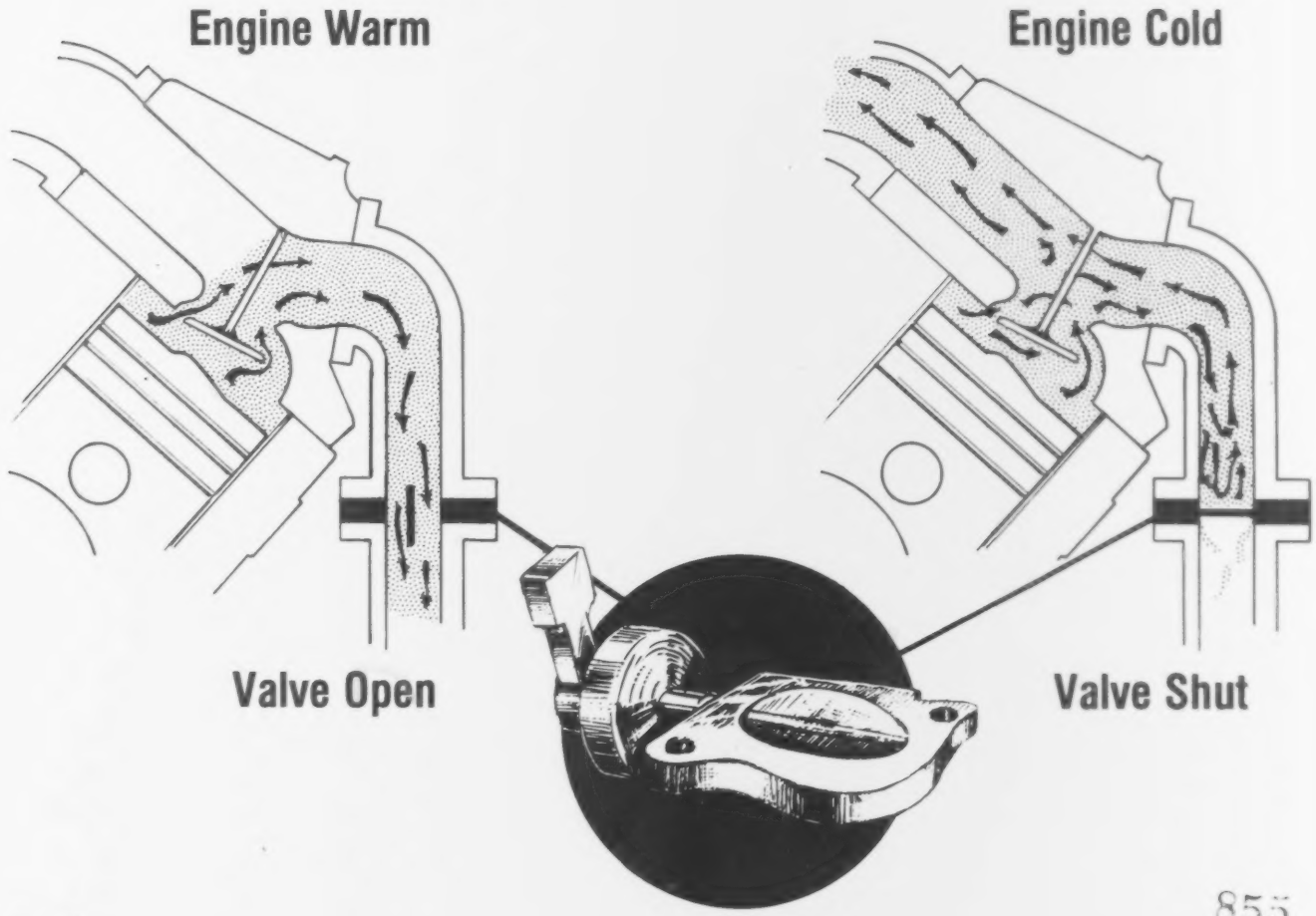
852

853

TM #4

HEM - 71-C

Operation of Manifold Heat-Control Valve



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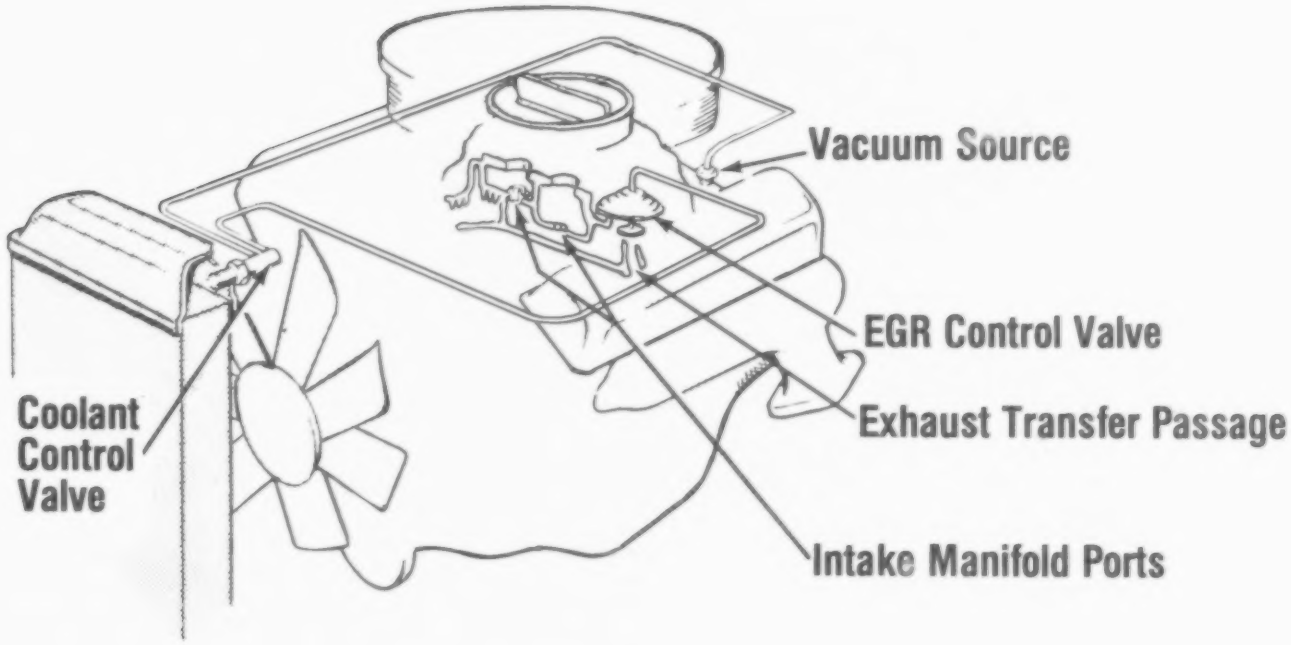
855

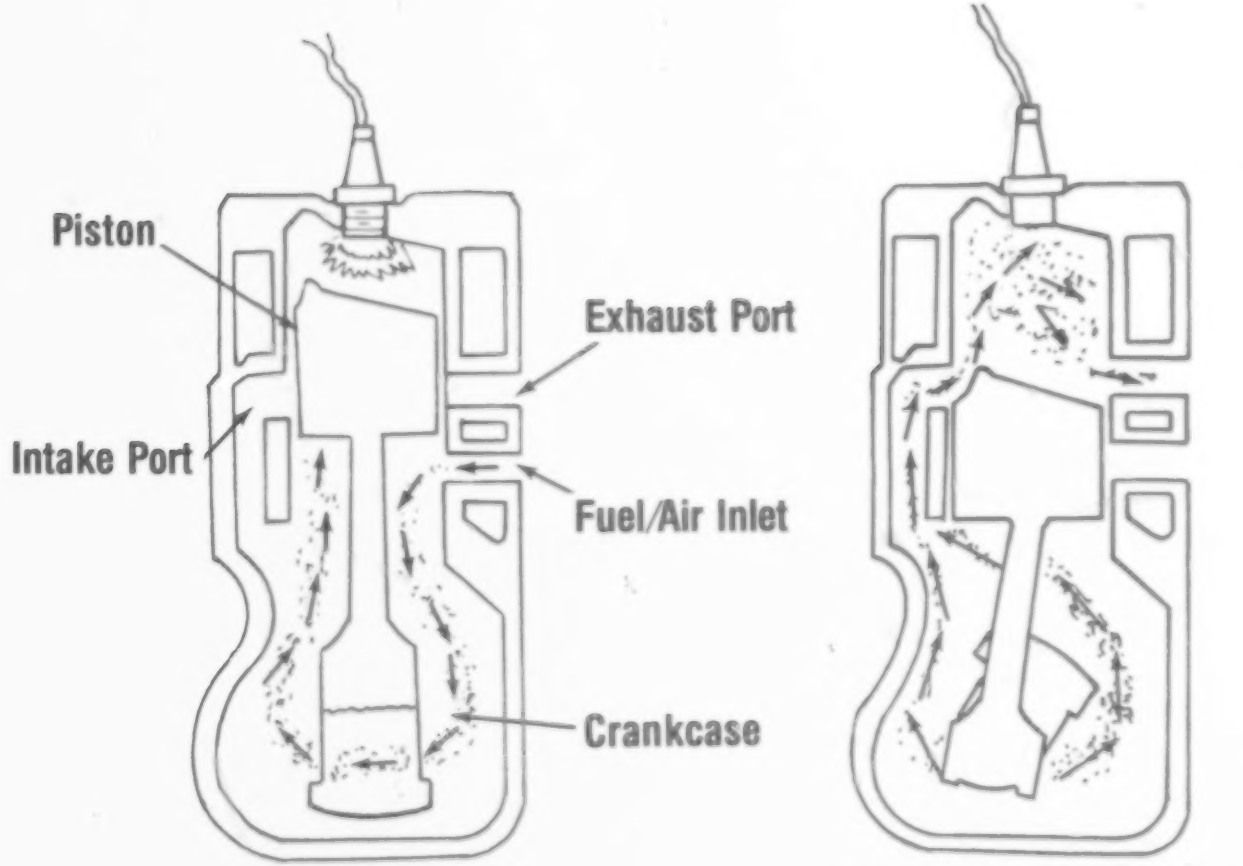
TM #5

HEM - 73-C

Exhaust-Gas Recirculating System



Crankcase-Scavenging Engine



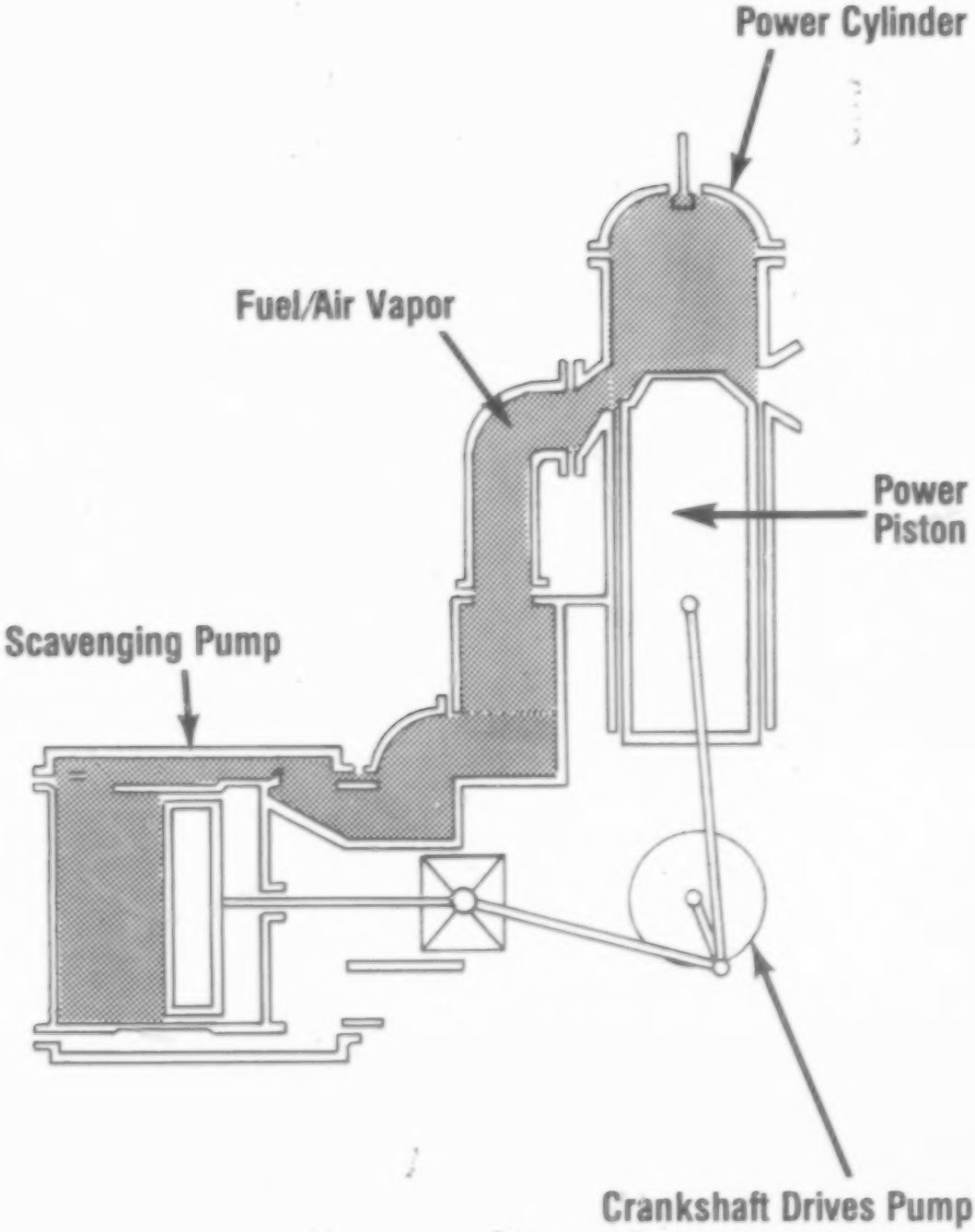
Compression/Power Stroke

Intake/Exhaust Stroke

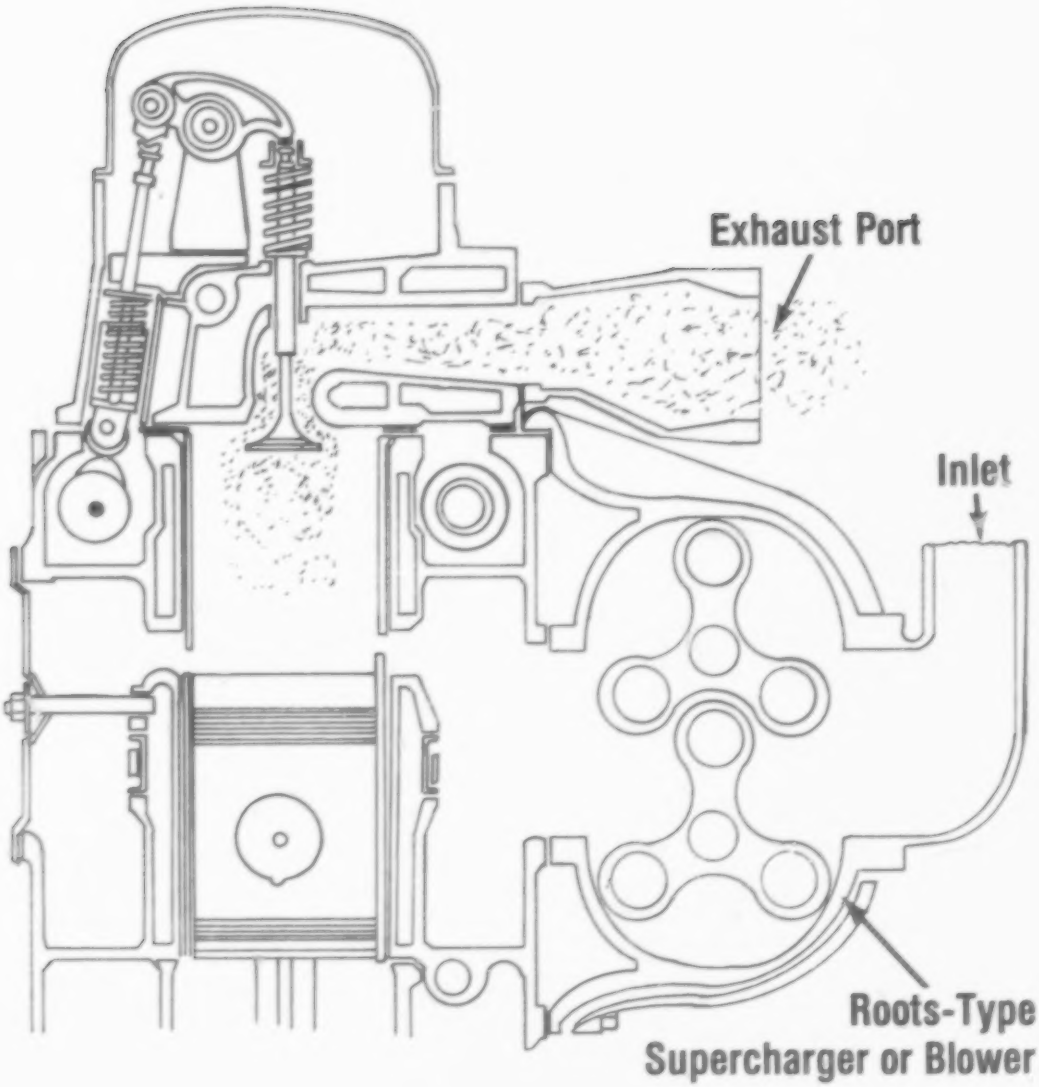
TM #7

HEM - 77-C

Scavenging Pump

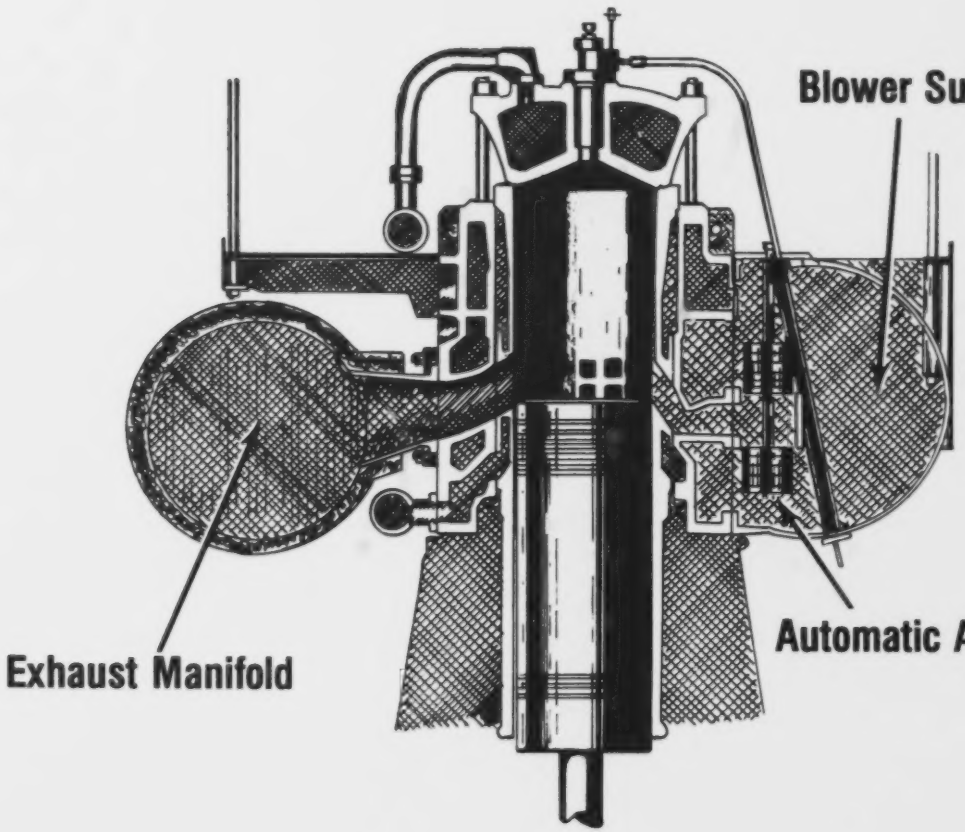


Blower



Positive Displacement

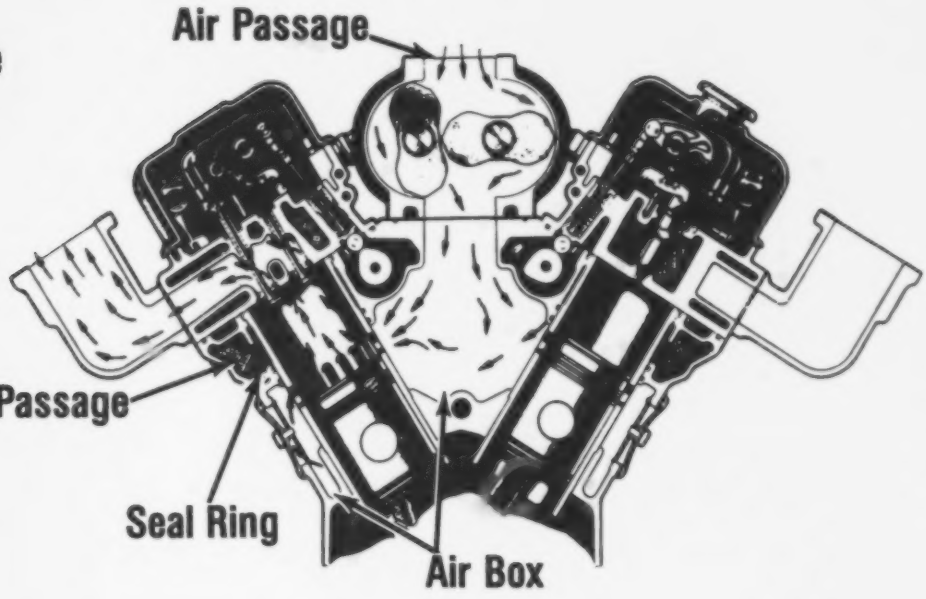
Port-Scavenging Engine



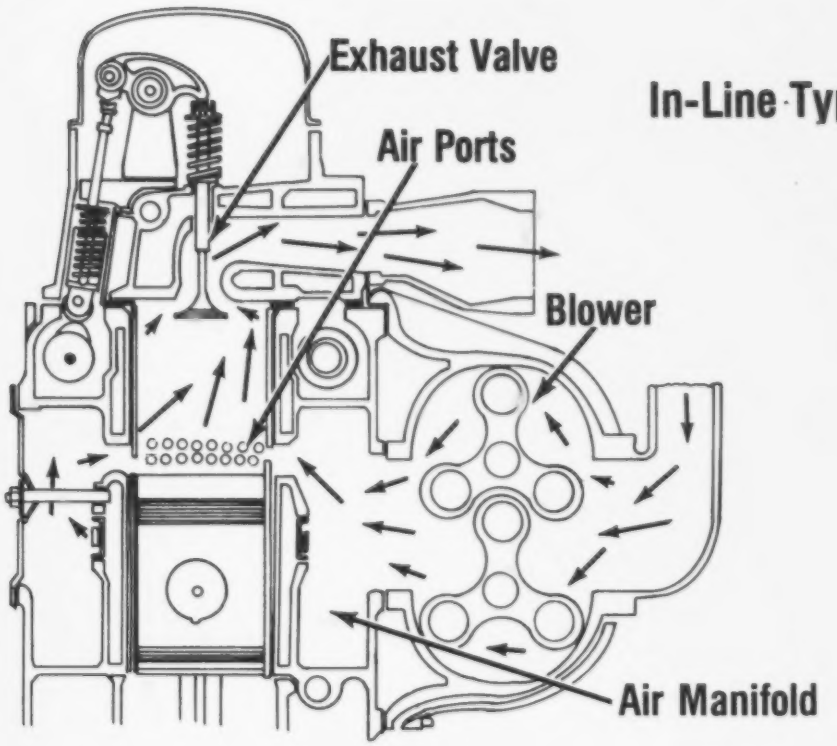
TM #10

Valve-Scavenging Engine

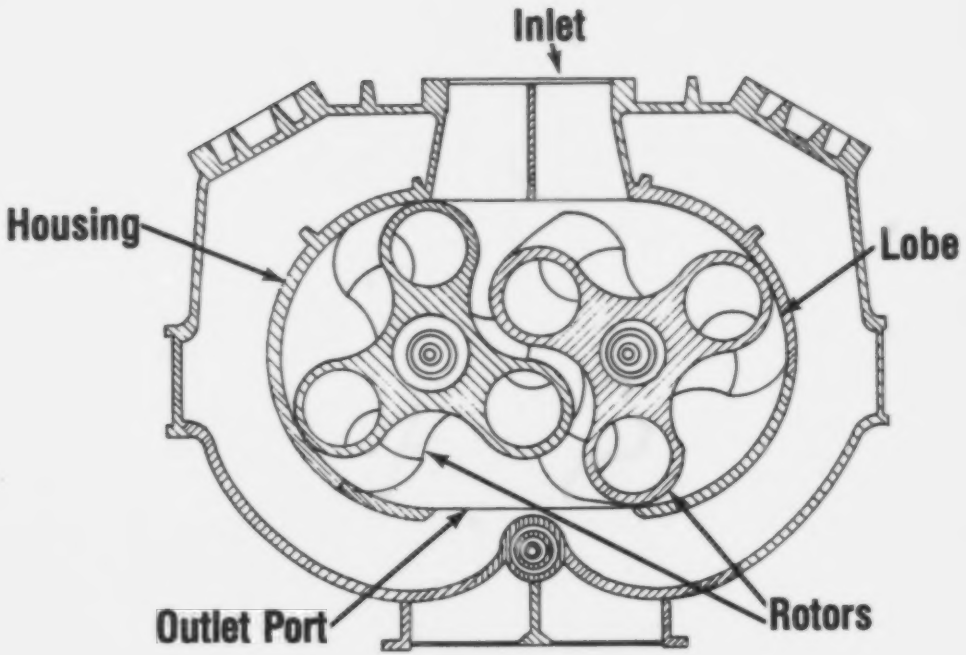
V-Type



In-Line Type

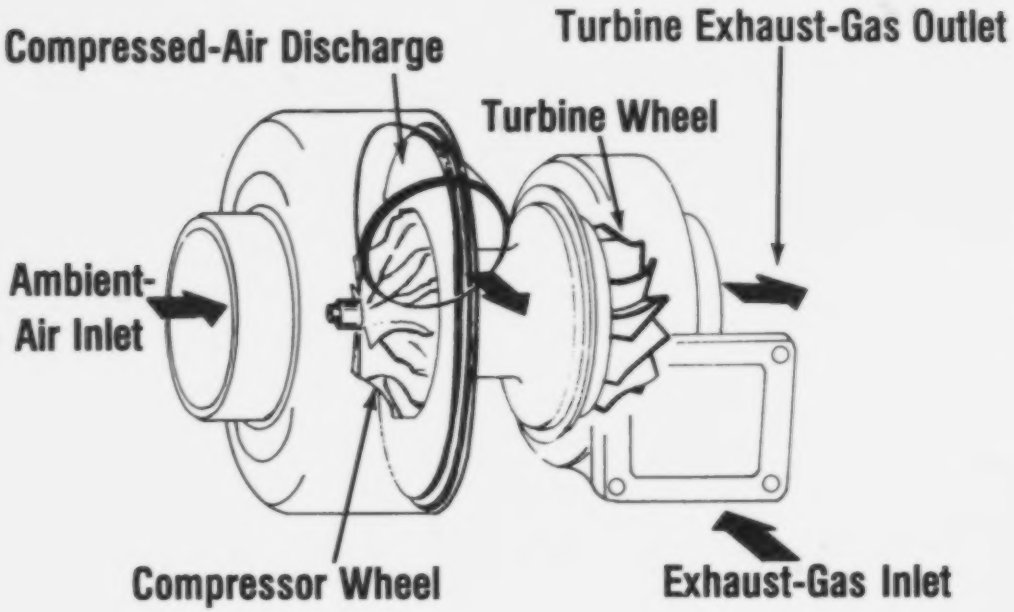


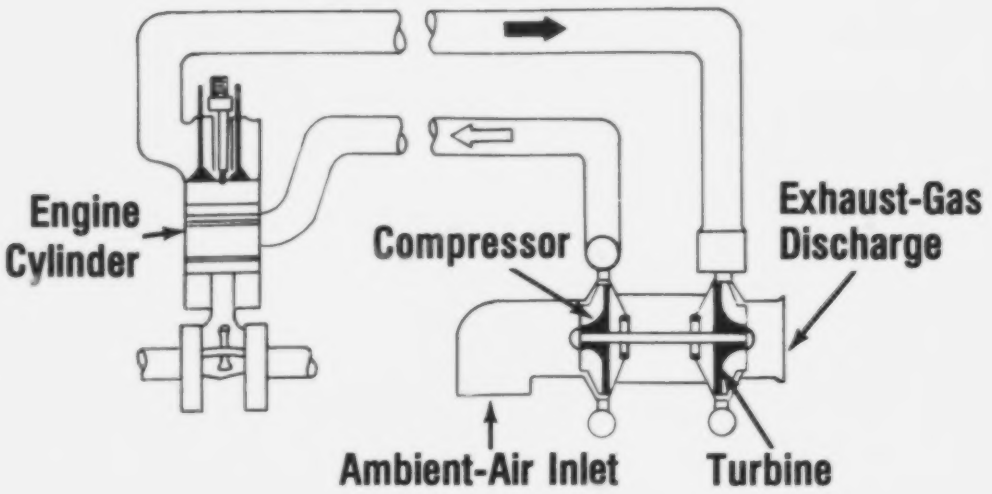
Positive-Displacement Supercharger



TM #12

Centrifugal-Type Supercharger





➡ Engine Exhaust-Gas Flow

⇨ Compressed-Air Flow

AIR-INTAKE AND EXHAUST SYSTEMS
UNIT II

JOB SHEET #1 — TEST AN ENGINE FOR AIR-FLOW RESTRICTIONS

I. Equipment and materials

A. Vacuum gauge

B. Basic hand-tool set

C. Live engine

D. Shop towels

E. Engine technical manual

F. Safety glasses

G. Appropriate service manual

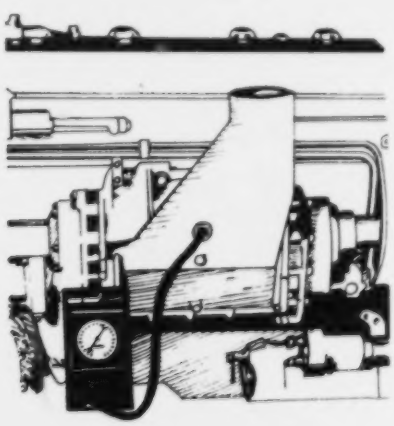
II. Procedure

(NOTE: When air flow is restricted, more vacuum or suction is in the cylinders. This vacuum or suction can cause oil to be drawn in around the valve stems and pistons and thus increase oil consumption.)

A. Warm up engine

B. Connect vacuum gauge to intake manifold (Figure 3)

FIGURE 3



JOB SHEET #1

C. Set engine speed at fast idle

D. Compare reading on gauge to specifications in engine technical manual

(NOTE: Too high a reading means that there is a restriction in the air-intake system.)

E. Clean work area; clean and put away all tools and equipment

AIR-INTAKE AND EXHAUST SYSTEMS
UNIT II

JOB SHEET #2 — SERVICE A MANIFOLD HEAT-CONTROL VALVE

I. Equipment and materials

A. Suitable manifold heat-control-valve solvent

B. Channel-lock pliers

C. Small ball-peen hammer

II. Procedure

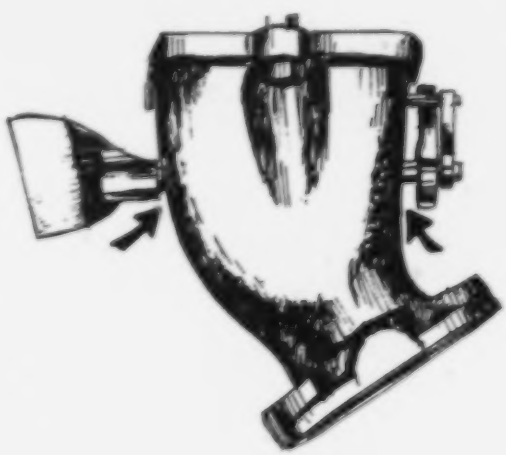
A. Locate manifold heat-control valve

(NOTE: On six-cylinder engines, valve is usually located in the center of the exhaust manifold under the carburetor. On V-type engines, valve is usually contained in the exhaust manifold or between the exhaust manifold and exhaust pipe on the right side.)

B. Apply manifold heat-control-valve solvent to both ends of valve shaft (Figure 4)

(NOTE: The manifold should be cool. Allow the solvent a few minutes to penetrate.)

FIGURE 4



JOB SHEET #2

C. Work the valve back and forth until it turns freely

(NOTE: If the valve remains stuck, tap lightly with the hammer, while working valve with channel-lock pliers. Continue procedure until the valve works freely.)

D. Make sure that the bimetal spring and antirattle spring are in place before concluding job

E. Clean work area; clean and put away all tools and equipment

AIR-INTAKE AND EXHAUST SYSTEMS
UNIT II

JOB SHEET #3 — REMOVE AND REPLACE AN EXHAUST MANIFOLD

I. Equipment and materials

A. Floor jack

B. Jack stands

C. Sockets, ½ inch to 11/16 inch, ⅜-inch drive

D. ⅜-inch drive extensions, 6 inch and 12 inch

E. ⅜-inch drive rachet

F. Combination wrenches, ½ inch to ¾ inch

G. ½-inch drive torque wrench

H. Socket adapter, ½ inch to ⅜ inch

I. Penetrating oil

J. Large, flat file

K. Appropriate service manual

II. Procedure

A. Lift vehicle with floor jack

B. Support vehicle on jack stands

C. Remove exhaust-pipe flange fasteners

(NOTE: You must saturate the fasteners with penetrating oil. Use extra care when removing fasteners to avoid twisting off the manifold studs.)

D. Lower exhaust pipe away from exhaust manifold

E. Remove crossover pipe if required

(NOTE: Use penetrating oil on fasteners. Avoid twisting off any bolts or studs securing the crossover pipe.)

F. Remove any braces or tubing that may be connected to exhaust manifold

JOB SHEET #3

G. Remove manifold retaining bolts

(NOTE: Use penetrating oil on retaining bolts. Avoid twisting off any bolts or studs securing the exhaust manifold.)

H. Remove exhaust manifold

(NOTE: The manifold should be checked for cracks and warpage.)

I. Clean mating surfaces of manifold with a large, flat file

(NOTE: Avoid cutting extra metal from manifold surface.)

J. Install new gaskets if required

K. Attach manifold; start retaining bolts

L. Tighten retaining bolts in sequence to avoid distortion

M. Torque retaining bolts to manufacturer's specifications

N. Install any braces or tubing that was removed

O. Clean mating surfaces of crossover pipe if required

P. Install new gaskets if required

Q. Install crossover pipe and tighten fasteners securely if required

R. Clean mating surfaces of exhaust pipe with file

S. Install new gaskets if required

T. Install exhaust pipe; start fasteners

U. Check exhaust-pipe alignment

(NOTE: Make sure that pipe does not contact frame, fuel lines, or hydraulic lines.)

V. Torque exhaust-pipe fasteners to manufacturer's specifications

W. Lower vehicle to floor

X. Start engine

Y. Check for leaks

(CAUTION: If leaks are present, repair them at once.)

Z. Clean work area; clean and put away all tools and equipment

AIR-INTAKE AND EXHAUST SYSTEMS
UNIT II

JOB SHEET #4 — REMOVE AND REPLACE AN EXHAUST PIPE

I. Equipment and materials

A. Floor jack

B. Jack stands

C. ⅜-inch drive sockets, ½ inch to 1 1/16 inch

D. ⅜-inch drive extensions, 6 inch and 12 inch

E. ⅜-inch drive ratchet

F. Suitable muffler-joint tools

G. Penetrating oil

H. ½-inch drive torque wrench

I. Socket adaptor, ½ inch to ⅝ inch

J. Chain wrench

K. Large, flat file

L. Appropriate service manual

II. Procedure

A. Lift vehicle with floor jack

B. Support vehicle on jack stands

C. Remove clamp from exhaust pipe and muffler joint

(NOTE: Saturate exhaust clamp fasteners and exhaust-pipe-to-muffler joint with penetrating oil.)

D. Remove muffler from exhaust pipe

(NOTE: You may need to use the chain wrench and heat to aid in breaking loose the muffler joint.)

E. Remove exhaust-pipe fasteners

(NOTE: Saturate exhaust-pipe fasteners with penetrating oil. Use extra care when removing fasteners to avoid twisting off the manifold studs.)

JOB SHEET #4

F. Remove any braces or hangers if required

G. Remove exhaust pipe

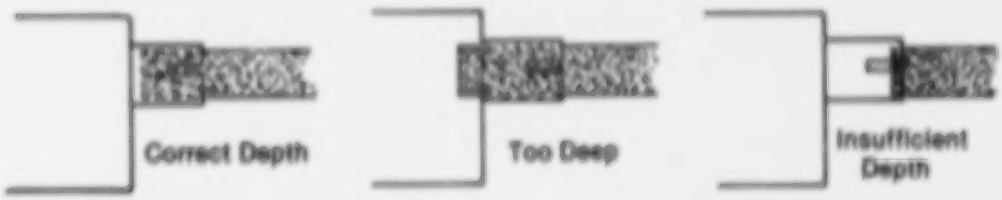
H. Clean mating surfaces of exhaust pipe and exhaust manifold with large, flat file

I. Install new gasket if required

J. Install exhaust pipe; start fasteners

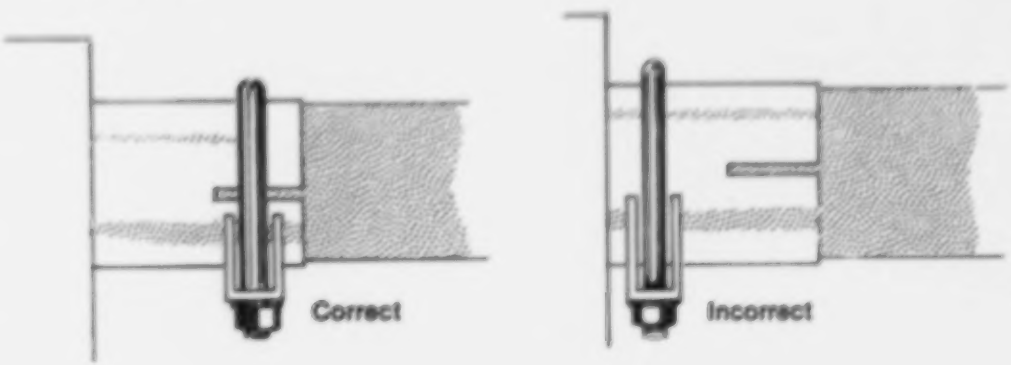
K. Position muffler on exhaust pipe (Figure 5)

FIGURE 5



L. Install exhaust-pipe clamp; start fasteners (Figure 6)

FIGURE 6



M. Align exhaust pipe and muffler

(NOTE: Make sure that exhaust pipe and muffler do not contact the frame, fuel lines, or hydraulic lines.)

N. Tighten exhaust-pipe retaining bolts to manufacturer's specifications

JOB SHEET #4

O. Tighten exhaust-pipe clamp securely

P. Install any braces or hangers that were removed

Q. Lower vehicle to floor

R. Start engine

S. Check for leaks

(CAUTION: If leaks are present, repair them at once.)

T. Clean work area; clean and put away all tools and equipment

AIR-INTAKE AND EXHAUST SYSTEMS
UNIT II

JOB SHEET #5 — REMOVE AND REPLACE A MUFFLER

I. Equipment and materials

- A. Floor jack
- B. Jack stands
- C. 3/8-inch drive sockets (preferably deep sockets), 1/2 inch to 5/8 inch
- D. 3/8-inch drive extensions, 6 inch
- E. 3/8-inch drive ratchet
- F. Suitable muffler-joint tools
- G. Penetrating oil
- H. Chain wrench

II. Procedure

- A. Lift vehicle with floor jack
- B. Support vehicle on jack stands
- C. Remove clamp at outlet end of muffler or exhaust hanger if necessary

  (NOTE: Apply penetrating oil to muffler joints and exhaust clamps.)
- D. Remove tailpipe from muffler

  (NOTE: You may need to use the chain wrench and heat to free the tailpipe from the muffler.)
- E. Remove clamp at inlet end of muffler

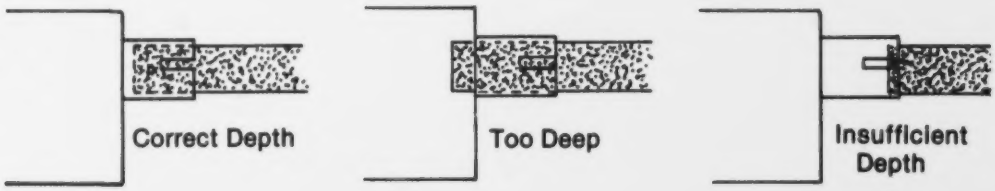
  (NOTE: Some mufflers are welded to the exhaust pipe and will have to be cut off.)
- F. Remove muffler from exhaust pipe

  (NOTE: Use penetrating oil, tapping, and heat if necessary to free the muffler joint.)
- G. Clean and straighten exhaust pipe and tailpipe if required
- H. Reinstall muffler
  1. Slide muffler onto exhaust pipe

JOB SHEET #5

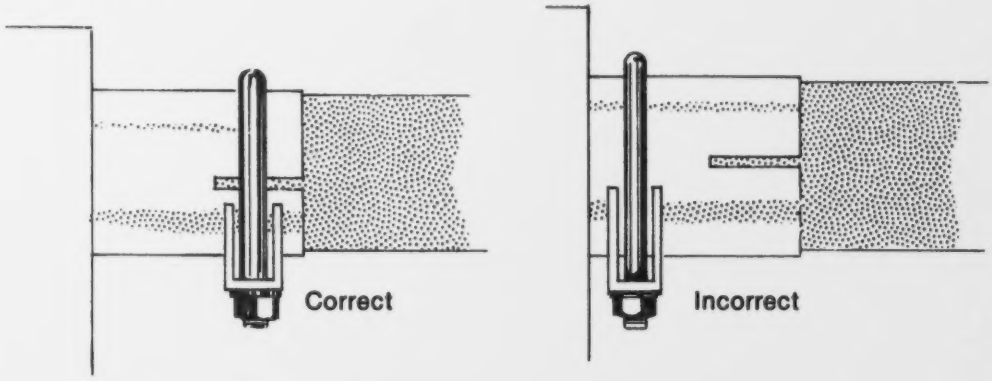
2. Slide tailpipe into muffler (Figure 7)

FIGURE 7



I. Place and start fasteners on clamps (Figure 8)

FIGURE 8



J. Position muffler on pipes and tighten clamps slightly

K. Recheck position of muffler and alignment of exhaust system

(NOTE: Make sure that the exhaust pipe, muffler, and tailpipe do not contact the frame, fuel lines, or hydraulic lines.)

L. Tighten exhaust clamps securely

(NOTE: Inspect all clamps and hangers to determine whether replacement is necessary.)

M. Lower vehicle to floor

N. Start engine

O. Check for exhaust leaks

(CAUTION: If leaks are present, repair them at once.)

P. Clean work area; clean and put away all tools and equipment

AIR-INTAKE AND EXHAUST SYSTEMS
UNIT II

JOB SHEET #6 — INSPECT A TURBOCHARGER FOR SATISFACTORY OPERATION

I. Equipment and materials

A. Basic hand-tool set

B. Live engine with turbocharger

C. Shop towels

D. Safety glasses

E. Engine technical manual

II. Procedure

A. Inspect turbocharger's mounting and connections to be certain that they are secure and that there is no leakage of oil or air

B. Check engine crankcase to be sure there is no restriction to oil flow

C. Operate engine at approximate rated output and listen for unusual turbocharger noise

(CAUTION: If a shrill whine [other than normal] is heard, stop the engine immediately. The whine means that the bearings are about to fail. Remove the turbocharger for inspection.)

(NOTE: As engine stops, do not confuse the whine heard during *run-down* with a bearing failure during operation. Other unusual turbocharger noises could mean improper clearance between the turbine wheel and housing. If such noises are heard, remove turbocharger for inspection. Refer to engine technical manual.)

D. Check turbocharger for unusual vibration while engine is operating at rated output

(NOTE: Unusual vibrations may require that the turbocharger be removed and inspected.)

E. Check engine under load conditions

(NOTE: Excessive exhaust smoke indicates incorrect fuel/air mixture. This could be due to engine overload or turbocharger malfunction.)

F. Inspect and service air cleaner according to instructions in technical manual

G. Clean work area; clean and put away all tools and equipment

AIR-INTAKE AND EXHAUST SYSTEMS
UNIT II

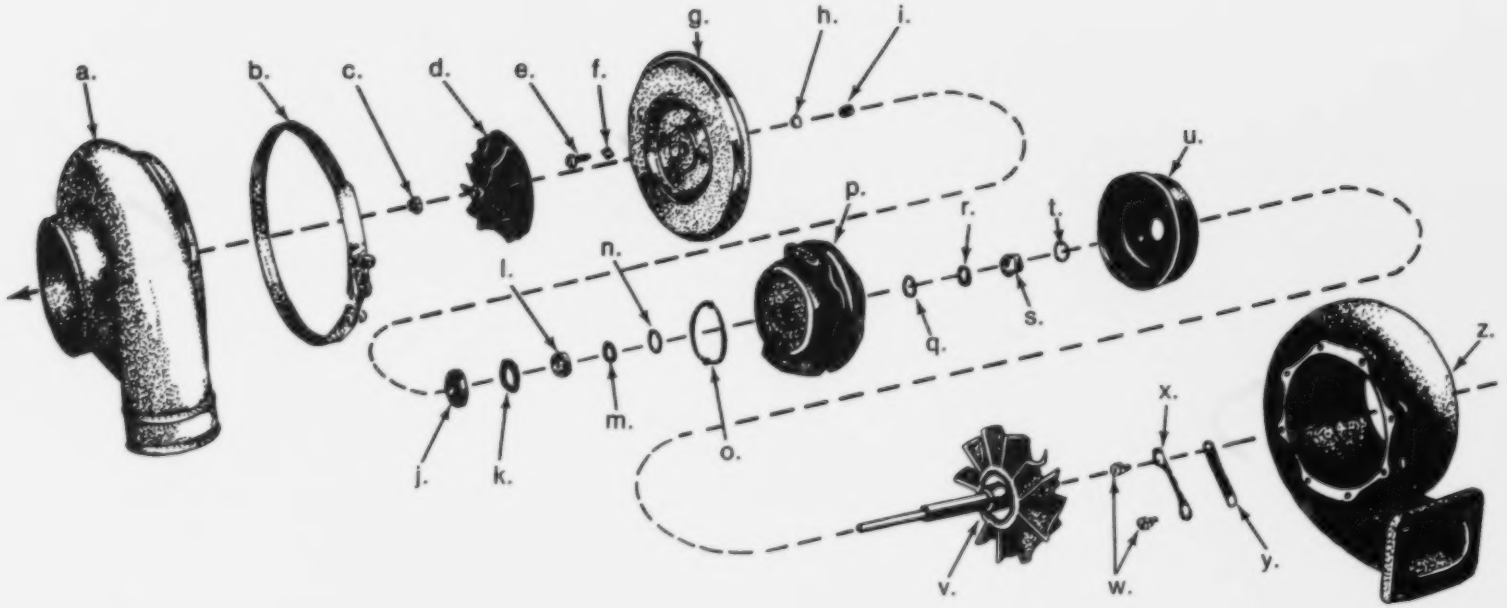
JOB SHEET #7 — REMOVE, DISASSEMBLE, SERVICE, ASSEMBLE, AND INSTALL A TURBOCHARGER

I. Equipment and materials

- A. Engine with turbocharger
- B. Basic hand-tool set
- C. Chain hoist
- D. Lifting sling
- E. Torque wrench
- F. Dial indicator with magnetic base, swivel adapter, extension rod
- G. Soft hammer
- H. Air compressor
- I. Noncaustic solvent
- J. Silicon carbide abrasive cloth
- K. Crocus abrasive cloth
- L. Eye protection
- M. Shop towels
- N. Appropriate service manual
- O. Double universal socket
- P. Tee handle

JOB SHEET #7

FIGURE 9



a. Compressor housing
b. V-band coupling
c. Self-locking nut
d. Compressor wheel
e. Screw
f. Lockplate
g. Backplate assembly
h. Piston ring
i. Thrust spacer
j. Thrust collar
k. Inboard thrust washer
l. Bearing
m. Bearing washer
n. Snap ring
o. Seal ring
p. Center housing
q. Snap ring
r. Bearing washer
s. Bearing
t. Snap ring
u. Turbine wheel shroud
v. Turbine wheel shaft assembly
w. Bolt
x. Lockplate
y. Turbine-housing clamp
z. Turbine housing

881

880

JOB SHEET #7

II. Procedure

A. Remove turbocharger

1. Disconnect exhaust manifold adapter attached to turbine housing
2. Disconnect air-inlet hose attached to compressor housing
3. Remove oil-inlet line from top of center housing
4. Remove oil-outlet line from bottom of center housing
5. Attach a chain hoist and suitable lifting sling to turbocharger assembly
6. Remove nuts and lock washers securing turbocharger assembly to mounting bracket
7. Lift turbocharger assembly away from engine and place on a bench
8. Cover the end of each oil inlet and outlet line, the air-inlet, and exhaust-outlet openings to prevent entry of foreign material
9. Clean exterior of turbocharger with noncaustic cleaning solvent

B. Disassemble turbocharger

(NOTE: Refer to Figure 9. Letters in parentheses in the text correspond to those in Figure 9.)

1. Loosen V-band coupling (*b*) securing compressor housing (*a*) to backplate assembly (*g*)
2. Remove compressor housing and V-band coupling
3. Remove the eight bolts (*w*) securing the four lockplates (*x*) and turbine-housing clamps (*y*) to center housing (*p*) and turbine housing (*z*)
4. Remove turbine housing from center housing

   (NOTE: Tap the housing with a soft hammer if force is needed for removal.)

   (CAUTION: Exercise care when removing center housing and turbine housing to prevent damage to turbine-wheel compressor.)
5. Position turbine wheel (*v*) of center housing assembly in a suitable holding fixture

6. Remove wheel nut (*c*) from shaft

   (CAUTION: To prevent the possibility of bending the turbine-wheel shaft, remove compressor-wheel nut from shaft with a double universal socket and tee handle.)

7. Press compressor wheel (*d*) from wheel shaft assembly (*v*)

8. Withdraw wheel shaft assembly and wheel shroud (*u*) from center housing

9. Remove the four screws (*e*) and lockplates (*f*) securing backplate assembly (*g*) to center housing (*p*)

10. Remove backplate assembly

11. Remove seal ring (*o*) from groove in center housing

12. Remove thrust spacers (*i*) and piston ring (*h*) from backplate assembly

13. Remove thrust collar (*j*), inboard thrust washer (*k*), bearing (*l*), bearing washer (*m*), and snap ring (*n*) from center housing

14. Remove snap ring (*t*), bearing (*s*), bearing washer (*r*), and snap ring (*q*) from opposite end of center housing

C. Clean turbocharger

(NOTE: Before cleaning, inspect parts for burns, abrasions, or other damage that might not be evident after cleaning.)

1. Soak all parts in noncaustic cleaning solvent for about twenty-five minutes

   (CAUTION: Never use a caustic cleaning solution, as this will damage certain parts. Use cleaning solution in an open or well-ventilated area. Avoid breathing the fumes. Keep away from open flames. Do not use a wire brush or a steel-bladed scraper to clean parts.)

2. After soaking, use a stiff-bristled brush to remove all dirt particles

3. Dry all parts thoroughly

   (NOTE: Make sure that both wheel blades are thoroughly clean. Deposits left on the blades will affect the balance of the rotating assembly.)

JOB SHEET #7

4. Clean all internal cavities and oil passages in center housing thoroughly with dry compressed air

   (CAUTION: Always wear eye protection when using compressed air.)

5. Clean oil passage in center-housing thrust plate with dry compressed air

6. Remove from engine the oil inlet and outlet lines; thoroughly clean oil lines inside and out

   (NOTE: An oil line that is dented or crimped enough to restrict the flow of oil must be replaced.)

D. Inspect turbocharger

1. Inspect all parts for signs of damage, corrosion, or deterioration

2. Check for nicked, crossed, or stripped threads

3. Visually check turbine wheel for signs of rubbing

4. Inspect shaft for signs of scoring, scratches, or bearing seizure

5. Check compressor wheel for signs of rubbing or damage from foreign material

6. Check to see that wheel bore is not worn

   (NOTE: The wheel must be free of dirt and other foreign material.)

7. Inspect parts of the seal for signs of rubbing or scoring of running races

8. Inspect housing for contact with rotating parts

   (NOTE: The oil and air passages must be clean and free of obstructions.)

9. Polish any minor surface damage that may appear

   (NOTE: Use a silicon carbide abrasive cloth for aluminum parts; use a crocus abrasive cloth for steel parts.)

10. Replace bearing and thrust washer if they show signs of nicks, scores, shellac deposits, or embedded foreign material

    (NOTE: It is recommended that when one rotor shaft bearing needs replacement, both bearings be replaced at the same time.)

11. Inspect the exhaust-outlet elbow seal ring for signs of wear or breakage

JOB SHEET #7

E. Assemble turbocharger

(NOTE: Check each part prior to installation to ensure cleanliness. As the parts are assembled, cover the openings to prevent entry of dirt or other foreign material. Letters in parentheses correspond to those illustrated in Figure 9.)

1. Lubricate bearings (*l* and *s*) with clean engine oil

2. Install a new snap ring (*q*), bearing washer (*r*), bearing (*s*), and snap ring (*t*) in turbine end of center housing (*p*)

3. Install a new snap ring (*n*), bearing washer (*m*), and bearing (*l*) in compressor end of center housing

4. Install a new piston ring (*h*) on thrust spacer (*i*) and gently insert spacer into backplate assembly (*g*)

   (NOTE: Do not force piston ring into place.)

5. Position inboard thrust washer (*k*) against center housing,aligning hole and cutout in thrust washer with pins in center housing

6. Install thrust collar (*j*) snugly against thrust washer

7. Lubricate thrust collar and thrust washer with clean engine oil

8. Install a new seal ring (*o*) in groove at compressor end of center housing

9. Align oil feed holes in center housing (*p*) and backplate assembly (*g*); attach backplate to center housing with four screws (*e*) and new lockplates (*f*)

10. Tighten screws to manufacturer's specified torque

    (NOTE: If a new backplate with a warning plate is inadvertently installed, the warning plate must be removed and the three drive screw holes plugged to prevent air leakage.)

11. Position wheel shroud (*u*) against center housing (*p*) and insert wheel shaft assembly (*v*) through wheel shroud and into center housing

    (NOTE: Be careful not to scuff or scratch the bearings when installing the shaft.)

12. Place turbine wheel shaft assembly, shroud, center housing, and backplate upright in a suitable holding fixture

13. Heat compressor wheel (*d*) in an oven, furnace, or hot oil bath to 325°F to 375°F for no more than ten minutes

14. Position compressor wheel over shaft (*v*) and install wheel retaining nut (*c*)

JOB SHEET #7

15. While compressor wheel is still hot, tighten nut to manufacturer's specified torque

16. After compressor wheel has cooled to room temperature, loosen retaining nut and inspect nut face and front face of compressor wheel to be sure that they are smooth and clean

17. Apply a small amount of clean engine oil to nut threads and to nut and wheel contact faces

18. Tighten retaining nut to manufacturer's specified torque

    (NOTE: When tightening retaining nut, do not impose a bending load on the shaft.)

19. Check bearing axial end play

    a. Clamp center housing assembly in bench vise equipped with soft jaws

    b. Fasten a dial indicator with magnetic base to center housing so that the indicator tip rests on end of rotating shaft on compressor side (Figure 10)

FIGURE 10

c. Move shaft axially back and forth by hand

(NOTE: If the total dial indicator readings do not fall within the manufacturer's specified limits, repair or replace the rotating assembly.)

20. Position turbine housing (*z*) against center housing (*p*) and secure with four clamps (*y*), four new lockplates (*x*), and eight bolts (*w*)

21. Torque bolts to 100 to 110 inch-pounds

22. Position compressor housing (*a*) against center housing (*p*) and secure it with V-band coupling (*b*)

23. Tighten nut on V-band coupling to manufacturer's specified torque

24. Check shaft radial movement

a. Position magnetic base with swivel adapter on flat surface of turbine-housing inlet flange

b. Fasten dial-indicator extension rod to dial indicator, and attach dial indicator to swivel adapter

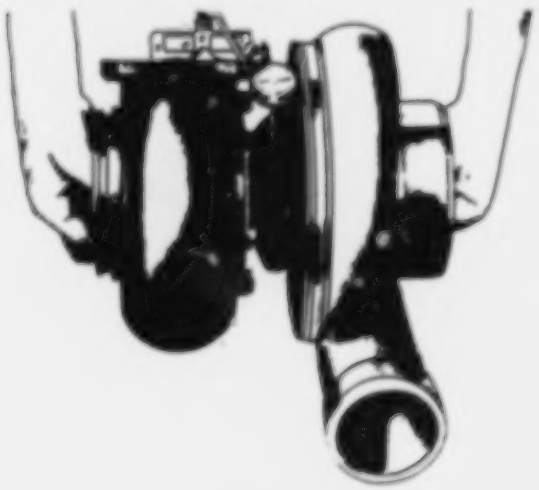
c. Insert extension rod into opening in oil drain-tube mounting pad so that rod is against and perpendicular to wheel shaft

(NOTE: Make sure that extension rod does not make contact with sides of center housing. If rod touches sides, it will be impossible to obtain an accurate reading.)

d. Grasp each end of rotating assembly and, applying equal pressure at each end, move shaft first toward and then away from dial indicator, creating a transverse movement in shaft (Figure 11)

(NOTE: If the displacement does not fall within these limits, disassemble and repair or replace the rotating assembly.)

FIGURE 11



25. Stamp the letter "R" in the lower left-hand corner of the nameplate to indicate that the turbocharger has been reworked

F. Install turbocharger

1. Attach chain hoist and suitable lifting sling to turbocharger assembly

2. Remove covers from air-inlet and exhaust-outlet openings on engine

(NOTE: Covers were placed over openings when the turbocharger was removed.)

3. Place turbocharger assembly into position on mounting bracket

4. Secure turbocharger to mounting bracket with bolts, lock washers, and nuts

(NOTE: Tighten nuts just enough to hold turbocharger tightly against bracket.)

5. Slide blower air-inlet hose over compressor-housing outlet opening; secure with hose clamps

6. Securely tighten turbocharger to exhaust manifold adapter bolts

7. Remove chain hoist and lifting sling from turbocharger

8. Install oil drain line between opening in bottom side of center housing and cylinder block

9. Attach oil-inlet line to cylinder block

10. Before starting engine, make sure that there is adequate lubricating oil in turbocharger

    a. Clean area around oil-inlet opening; then pour about 4 ounces of engine oil in oil-inlet opening of center housing

    b. Turn rotating assembly by hand to coat bearings, thrust washers, and thrust collar with oil

    c. Hold compressor wheel from turning; start engine, and run it at idle speed

    d. As soon as oil appears at end of oil supply line, connect oil-inlet line to top of center housing

       (NOTE: Compare oil pressure to manufacturer's specification.)

    e. After oil-inlet line is attached, release compressor wheel

11. Check all ducts and gaskets for leaks

12. Operate engine at idle speed for a short period to provide adequate lubrication to turbocharger bearings

13. Run at rated output and listen for sounds of metallic contact from turbocharger

    (NOTE: If any such noise is apparent, shut down engine immediately and correct the cause. After the turbocharger has been operating long enough to permit the unit and the oil to warm up, the rotating assembly should coast freely to a stop after the engine is stopped. If the rotating assembly jerks to a sudden stop, the cause should be immediately determined and the problem eliminated.)

G. Clean work area; clean and put away all tools and equipment

AIR-INTAKE AND EXHAUST SYSTEMS
UNIT II

JOB SHEET #8 — DISASSEMBLE, SERVICE, REPAIR AND ASSEMBLE A SUPERCHARGER

I. Equipment and materials

A. Basic hand-tool set

B. Arbor press

C. Vise with protective jaws

D. Feeler gauge

E. Soft hammer

F. Lock wire

G. Compressed air source

H. Noncaustic solvent

I. Mineral spirits

J. Shop towel

K. Eye protection

L. Appropriate service manual

M. Emery cloth

N. Spanner wrench

O. Puller

P. Coupling locking wrench

Q. Dial indicator

R. V-blocks

S. Wooden block

JOB SHEET #8

II. Procedure

A. Disassemble supercharger

(NOTE: Visually inspect rotors and case surfaces through inlet and outlet ports before disassembling supercharger. If severe scoring, roughness, or cracks are found, replace entire assembly with a rebuilt unit.)

1. Remove intake and discharge connections
2. Cover both openings, and wash exterior of supercharger with mineral spirits

   (CAUTION: Do not use any solution that will damage finished surfaces or aluminum.)
3. Mount supercharger in vise, clamping supercharger at intake housing only tightly enough to stabilize it

   (NOTE: Make sure that vise jaws are covered with copper or other protective material.)
4. Remove pipe bushing from end plate cover; remove oiler spring and plunger
5. Pry up on collar on recessed washer at rear, or drive, rotor shaft; remove locknut and washer

   (NOTE: Some models require a special spanner wrench.)
6. Remove generator drive coupling, if used

   (NOTE: Some models require a special puller.)
7. Remove capscrews from end plate cover
8. Carefully pry cover from dowels, using a small screwdriver at each end of cover
9. Drive out oil seal
10. Pry ears of recessed washer up and out of slots in locknut on rotor shafts at plain end of supercharger, and pry up ears of recessed washer in locknut on drive coupling at gear end of supercharger
11. Lock rotors with coupling locking wrench; remove locknut at plain end and locknut on drive coupling
12. Use puller to remove drive coupling from shaft

JOB SHEET #8

13. Remove drain plug from bottom of gear cover; drain oil

14. Remove capscrews from gear end plate cover; remove cover

15. Remove oiler retainer, spring key washer, and plug from gear cover

16. Remove locknut and lock washer from idler rotor shaft end, using shaft locking wrench to lock rotors

17. Remove socket head capscrews from gear end plate

18. Remove end plate rotor and gears as a unit from housing

19. Carefully tap plate at each end with rubber hammer to remove from housing dowels

20. Check each rotor for proper timing marks and position

    (NOTE: One rotor will have an "X" mark along the gear end of the air line. The other rotor will have an "X" mark in the gear end of the valley. When properly assembled, these two "X" marks will pass together each time the supercharger rotates. If the rotors do not have timing marks, it will be necessary to mark the rotors prior to removal from end plate. When reassembling the unit, the rotors must operate in the same position as they did before disassembly. Keep all rotors in matched pairs when rebuilding more than one unit.)

21. Support underside of end plate near rotors and press out each rotor shaft

22. Mark each gear so that it can be replaced on shaft from which it was removed

23. Remove rotors from housings

    (NOTE: When rotors are removed from housings, inner races of roller bearings usually remain on shafts. Remove them carefully, avoiding damage to shafts.)

24. Remove screws from each bearing retainer plate on gear end plate; remove retainers

25. Press bearings out of gear end plate

26. Remove capscrews from plain end plate

27. Remove end plate from housing dowels by carefully tapping plate at each end with a rubber hammer

28. Drive bearing outer races and rollers out of end plate

29. Remove piston ring seals from both ends of rotor shafts

B. Clean and inspect supercharger

1. Discard all gaskets, oil seals, recessed washers, roller bearings, and ball bearings

2. Clean all parts with approved cleaning solvent; dry thoroughly

3. Inspect rotors, housing, and end plates for cracks, abrasions, wear spots, and build-up of foreign material; smooth all worn or rough spots with fine emery cloth

4. Wash in approved solvent and dry

5. Discard cracked, broken, or damaged parts

   (NOTE: Rotors and shafts are not separable and must be replaced as a matched set or unit.)

6. Inspect drive coupling for worn pins, distorted or displaced rubber bushings, and damaged or worn internal splines

7. Examine hub surface under oil seal; replace coupling if surface is grooved or seriously worn

8. Check gear fit on rotor shafts, matching gears to shafts from which removed

9. Check gear teeth for evidence of chatter and wear

10. Replace rotors and gears if gears are not a good press-fit on shafts

11. Mount gears on 4-inch centers and check backlash between gears

    (NOTE: Compare reading with manufacturer's specifications.)

12. Mount drive rotor on V-blocks at bearing journals

13. Set up dial indicator to bear on outside diameter of splines at shaft ends

    (NOTE: Check manufacturer's specifications for runout readings.)

14. Inspect all dowels, oiler plungers, piston-ring seals, and gasket surfaces; replace as necessary

JOB SHEET #8

C. Repair and assemble supercharger

1. Press new double-row ball bearings into gear end plate
2. Position bearing retainers and secure with screws and lock washers
3. Install piston seal rings on rotor shafts
4. Use wooden block to construct an assembly block

   (NOTE: Drill holes slightly larger than shaft diameter.)
5. Position rotors on block with plain end of shafts in holes, gear end up

   (CAUTION: Do not damage shaft seal rings.)
6. Move block of wood with rotors in place to arbor press, and install gear end plate so that rotor shafts enter proper bearings
7. Press bearings over shafts with appropriate mandrel and sleeve

   (CAUTION: Make certain that seal rings on rotor shafts enter end plate without damage.)
8. Install temporary spacers on shaft ends
9. Install and tighten two shaft locking nuts

   (NOTE: Some superchargers require a special shaft locking wrench.)
10. Check end clearance with feeler gauge

    (NOTE: If manufacturer's specified clearance is not obtained, remove locknuts and temporary spacers; press rotor shafts from bearings.)
11. Add or remove shims between shaft shoulder and bearing inner race to obtain manufacturer's specified clearance
12. Reassemble parts and recheck clearances
13. Repeat above procedure, if necessary, until proper clearance is obtained
14. Remove two locknuts and temporary spacers from rotor shafts
15. Press same gear on drive shaft that was removed, unless new gears are used

JOB SHEET #8

16. Position rotors at right angles to each other with timing marks in proper position, and press other gear on idler rotor shaft

    (NOTE: The rotor timing marks will only ensure the proper valley-to-lobe relationship. When installing gears, the rotors must be at a 90-degree angle to each other. Disregard timing marks on gears.)

17. Remove rotor and end plate assembly from arbor press

18. Separate inner races or new roller bearings and drive races on plain ends of rotor shafts

19. Assemble rotor, end plate, and gear assembly to housing, using new gasket

20. Install socket head capscrews with new copper washers

21. Tighten evenly and securely, using lockwire to secure

22. Position plain end plate on housing

    (NOTE: Engage dowels evenly in proper holes; assemble capscrews and lock washers and tighten evenly on alternate sides.)

23. Install new roller-bearing outer races, and rollers over inner races, into plain end-plate bore

    (NOTE: Make certain that bearing name is toward outside.)

24. Check clearances between rotors and rotor housing, rotors and plain end plate, and between rotors

    (NOTE: Use long feeler gauge through inlet and outlet ports of housing.)

25. Check clearance between rotors

    (NOTE: If clearances cannot be obtained, disassemble and thoroughly check all parts. Additional shims can be installed between gear end plate and housing to obtain proper clearance at opposite ends of rotors and plain end plate. If other clearances cannot be obtained, replace supercharger.)

26. Position new recessed washers on each end of driven motor shaft, and install two nuts

    (NOTE: Hold drive shaft by placing a clean block of wood between rotors. Tang on inner part of washer must fit into keyway of shaft. Tighten nuts with special spanner wrench; stake side of washer into slot of nut after tightening.)

JOB SHEET #8

27. Assemble new gasket to plain end plate and install end-plate cover

28. Install lock washers and capscrews and tighten evenly

29. Install one new oil seal in cover bore

    (NOTE: Sealing lips should be toward rotors and flush with housing.)

30. Press generator drive coupling on shaft

    (NOTE: While pressing on coupling, always rest unit on opposite end of shaft.)

31. Install generator coupling lock washer and locknut

32. Tighten locknut securely and lock

33. Replace oiler plunger and spring in gear cover

    (NOTE: Make sure that small oil hole is clean and slots in plunger line up with spring retainer fitting, or cover will not pull up to end plate.)

34. Install new oil seal flush with gear cover, with sealing lips in

35. Assemble cover with a new gasket-to-gear end plate, and install lock washers and capscrews

36. Tighten securely on alternate sides

37. Assemble oiler plunger, spring, and fitting into plain end of bearing cover

    (NOTE: Radius on end of pin must fit radius of spacer. Oil hole must be clean, and pin must work freely.)

38. Replace oil drain-hose fitting in gear end cover

39. Support entire assembly on drive rotor shaft at plain end; press drive coupling onto splines at drive end

    (NOTE: Press on coupling flange, not pins.)

40. Install recessed washer and nut to drive rotor shaft threads

41. Tighten securely with special spanner wrench

42. Hold shaft from turning with coupling locking wrench

43. Lock washer into nut slots after tightening

JOB SHEET #8

44. After supercharger is installed, add 1 quart of engine lubricating oil to gear end plate through pipe plug hole

D. Clean work area; clean and put away all tools and equipment

AIR-INTAKE AND EXHAUST SYSTEMS
UNIT II

TEST

NAME _____ SCORE _____

1. Match to their correct definitions terms associated with exhaust systems. Write the correct numbers in the blanks. Definitions are continued on the following page.

_____a. Method of pushing air out of cylinders during exhaust stroke on two-cycle engines

_____b. Device for increasing air pressure and velocity

_____c. Valve located in exhaust manifold; deflects a certain amount of hot gas around carburetor base to aid engine warm-up

_____d. Circular bolt used to clamp exhaust pipe to muffler

_____e. Exhaust-driven turbine that drives a centrifugal compressor

_____f. Pipe connecting engine exhaust ports to exhaust pipe; usually made of cast iron

_____g. Chamber through which exhaust gases are passed to quiet the sounds of the engine

_____h. Method of charging cylinders on the intake stroke with fresh air above atmospheric pressure

_____i. Not supercharged

_____j. Device that collects some dirt from the air before air enters main air cleaner

_____k. Pipe used on V-type engines to connect exhaust manifolds entering a single exhaust pipe

_____l. Material that when present increases the rate of chemical reaction in exhaust gases

1. Pipe clamp
2. Manifold heat-control valve
3. Supercharging
4. Exhaust pipe
5. Crossover pipe
6. Pipe hanger
7. Turbocharger
8. Exhaust manifold
9. Muffler
10. Catalyst
11. Scavenging
12. Naturally aspirated
13. Valve
14. Precleaner
15. Filter
16. Blower

TEST

_____m. Unit containing a material of varying degrees of fineness to trap foreign particles

_____n. Device for sealing cylinder-head intake or exhaust ports

_____o. Pipe connecting exhaust manifold to muffler

_____p. Metal and fabric strap used to support the exhaust system

2. List parts of an air-intake system.

a. _____

b. _____

c. _____

d. _____

e. _____

3. Discuss types of air cleaners.

a. Dry element — _____

_____

_____

b. Viscous impingement — _____

_____

_____

c. Wet (oil bath) — _____

_____

_____

4. State the purpose of the exhaust system.

_____

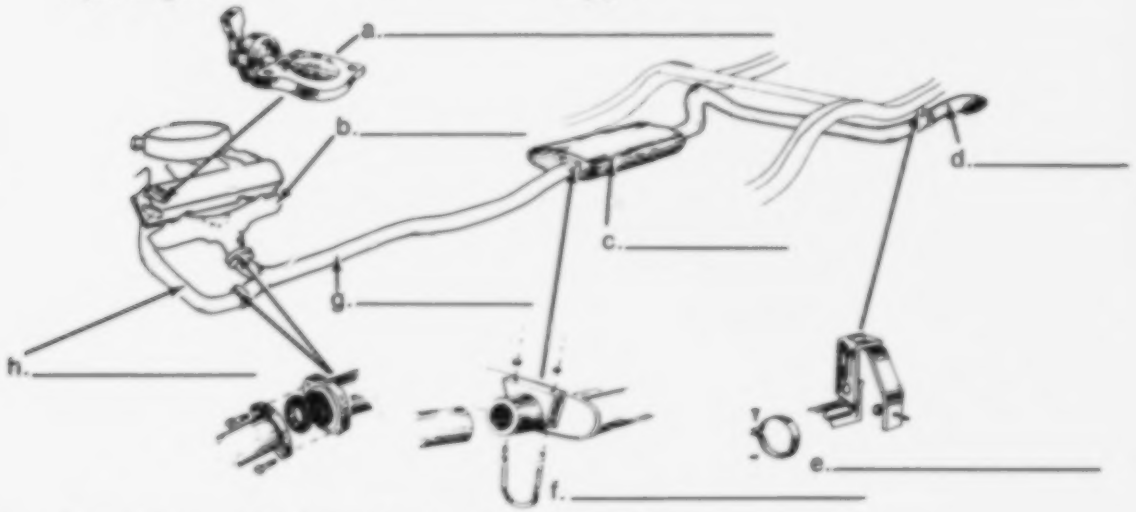
_____

_____

TEST

5. Identify components of the exhaust system illustrated below. Write the correct names in the blanks.

Manifold heat-control valve
Crossover pipe
Pipe clamps
Pipe hangers
Exhaust manifold
Exhaust pipe
Mutfler
Tailpipe



6. Describe operation of the manifold heat-control valve.

a. Engine cold — _____

_____

b. Engine warm — _____

_____

7. Distinguish between internal and external causes of exhaust system corrosion. Write an "I" in the blanks describing internal causes and an "E" in the blanks describing external causes.

_____a. Water mixing with exhaust gases creates a light acid that etches exhaust metal

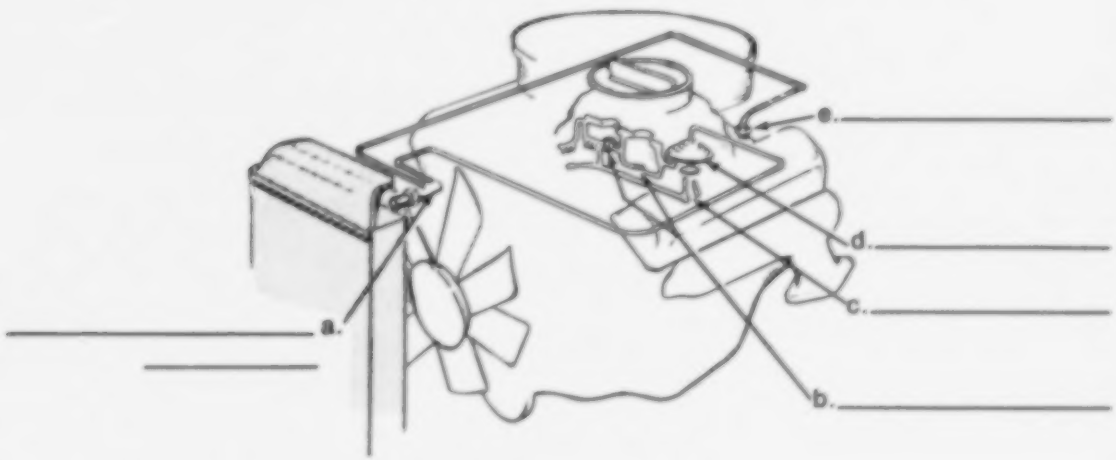
_____b. Rusting occurs due to rain, snow, and humidity

_____c. Water caused by combustion process collects in muffler

_____d. Corrosion is accelerated when equipment is in contact with salt, calcium, or lime

TEST

8. Label basic components of the exhaust-gas recirculating system illustrated below. Write the correct names in the blanks.



9. State the purpose of the exhaust-gas recirculating system.

10. Discuss methods of scavenging the cylinders on a two-stroke-cycle engine.

a. Crankcase —

b. Power piston —

c. Blower —

TEST

11. Distinguish between port and valve scavenging on a two-stroke-cycle engine. Write an "X" in the blank before port scavenging.

_____a. Air enters through ports in cylinder block, and gases leave through valves in cylinder head

_____b. Air enters and gas leaves through ports in cylinder block or liner that piston uncovers

12. Distinguish between types of superchargers. Write a "P" in the blanks before positive displacement and a "C" in the blanks before centrifugal.

_____a. Driven by engine, engine exhaust, or separate motor

_____b. Driven by a chain, belt, or gear

_____c. Resembles oil pump in design

_____d. Moves impeller thirty times engine speed

13. Select from the following list advantages of a turbocharged engine. Write an "X" in the blank before each correct answer.

_____a. Reduces exhaust smoke by supplying excess air to reduce exhaust density

_____b. Increases horsepower output of a given displacement engine

_____c. Reduces weight by delivering more horsepower per pound than nonturbocharged engines

_____d. Reduces horsepower at high altitudes

_____e. Costs less on a dollar-per-horsepower basis than nonturbocharged engines

14. List three safety precautions pertaining to exhaust systems.

a. _____

_____

b. _____

_____

c. _____

_____

TEST

(NOTE: Test question 15 lists the job sheets. They are an important part of this test. If they have not been completed, check with your instructor.)

15. Demonstrate the ability to

    a. Test an engine for air-flow restrictions.

    b. Service a manifold heat-control valve.

    c. Remove and replace an exhaust manifold.

    d. Remove and replace an exhaust pipe.

    e. Remove and replace a muffler.

    f. Inspect a turbocharger for satisfactory operation.

    g. Remove, disassemble, service, assemble, and install a turbocharger.

    h. Disassemble, service, repair, and assemble a supercharger.

AIR-INTAKE AND EXHAUST SYSTEMS
UNIT II

ANSWERS TO TEST

1.	a.	11	e.	7	i.	12	m.	15
	b.	16	f.	8	j.	14	n.	13
	c.	2	g.	9	k.	5	o.	4
	d.	1	h.	3	l.	10	p.	6

2. a. Precleaner, air cleaner
   b. Supercharger (where applicable)
   c. Intake manifold
   d. Piping
   e. Intake valves or ports

3. Discussion should include the following
   a. Cleans air by passing it through a maze of metal wool, wire, or screens
   b. Cleans air by passing it through a maze of metal wool, wire, or screens saturated with oil
   c. Cleans air by directing it through a center tube into an inner oil cup where direction of air flow is reversed, thus causing most of the dirt to become trapped by the oil and to settle in the sump

4. To scavenge exhaust gases efficiently from the combustion chamber and conduct them to the outside air with a minimum of noise

5. a. Manifold heat-control valve
   b. Exhaust manifold
   c. Muffler
   d. Tailpipe
   e. Pipe hangers
   f. Pipe clamps
   g. Exhaust pipe
   h. Crossover pipe

ANSWERS TO TEST

6. Description should include the following

   a. Engine cold — Heat-control valve is shut to allow exhaust gases to pass under carburetor base to bring about better fuel atomization and warm-up

   b. Engine warm — Heat-control valve is open to allow exhaust gases to pass out to exhaust system

7. a. I c. I

   b. E d. E

8. a. Coolant control valve

   b. Intake manifold ports

   c. Exhaust transfer passage

   d. EGR control valve

   e. Vacuum source

9. To reduce oxides of nitrogen in engine exhaust gases by lowering peak flame temperature during combustion

10. Discussion should include the following

    a. Crankcase

       1) Air enters engine through crankcase

       2) Each downward movement of piston compresses vapor within crankcase until intake port or valve opens

       3) Compressed vapor escapes into cylinder at a pressure nearly equal to atmospheric pressure

    b. Power piston — Separate piston driven by engine crankshaft pushes vapor into cylinder as intake valve or port opens

    c. Blower — Positive-displacement rotary blower driven by engine compresses vapor into air chamber surrounding intake ports

ANSWERS TO TEST

11. b

12. a. C
    b. P
    c. P
    d. C

13. a, b, c, e

14. Answer should include any three of the following
    a. Do not operate engines in a closed area without adequate ventilation
    b. Repair leaks in exhaust system immediately
    c. Do not operate equipment from a closed cab without adequate ventilation
    d. Do not touch any part of exhaust system when it is hot
    e. When operating an engine in the shop, use shop's exhaust-ventilation system

15. Performance skills evaluated to the satisfaction of the instructor

FUEL SYSTEMS
UNIT III

UNIT OBJECTIVE

After completing this unit, the student should be able to remove and service components of the fuel system. The student will show this knowledge by completing job sheets and unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match terms associated with fuel systems to their correct definitions.
2. State the purpose of the fuel system.
3. Label components of gasoline and diesel fuel systems.
4. Match fuel system components to their correct purposes.
5. Describe fuel pump operation during inlet and outlet strokes.
6. List major functions of the fuel injection system.
7. Label basic parts of a carburetor.
8. Match carburetor systems to their correct uses.
9. Name the three major types of fuel injection systems.
10. Describe variations of fuel injection systems.
11. List methods of injecting fuel using the pump and injection nozzle.
12. Identify types of fuel filters.
13. Distinguish between operation of series and parallel dual filters.
14. Identify types of air cleaners.
15. Match types of fuel lines to their correct purposes.

OBJECTIVE SHEET

16. Demonstrate the ability to

    a. Volume and pressure test a fuel pump.

    b. Remove and replace a fuel pump.

    c. Inspect air cleaner service indicator and service air cleaner.

    d. Service oil-bath-type air cleaner.

    e. Remove and replace an in-line fuel filter.

    f. Remove and replace a carburetor.

    g. Disassemble, adjust, and reassemble a carburetor.

FUEL SYSTEMS
UNIT III

SUGGESTED ACTIVITIES

I. Suggested activities

A. Order films to supplement unit.

(NOTE: Engine manufacturers are excellent sources for slide and film presentations on gasoline and diesel engines. Write directly to the appropriate company or manufacturer.)

B. Obtain transparencies.

(NOTE: Transparencies are available from AGC and CIMC.)

C. Gather equipment and materials for job sheet demonstrations.

D. Check with major engine manufacturers for visual aids to demonstrate fuel systems.

E. Provide students with objective sheet.

F. Discuss unit and specific objectives.

G. Provide students with information and job sheets.

H. Discuss information sheet.

I. Demonstrate and discuss procedures outlined in job sheets.

J. Give test.

K. Complete appropriate section of competency profiles.

(NOTE: Competency profiles are available from AGC and CIMC.)

II. Instructional materials

A. Objective sheet

B. Suggested activities

C. Information sheet

D. Transparency masters

1. TM #1 — Fuel System Components (Gasoline)

2. TM #2 — Fuel System Components (Diesel)

SUGGESTED ACTIVITIES

3. TM #3 — Fuel Pump Operation
4. TM #4 — Parts of the Carburetor
5. TM #5 — Float System
6. TM #6 — Idle System
7. TM #7 — Main Metering System
8. TM #8 — Power System
9. TM #9 — Accelerator Pump System
10. TM #10 — Choke System
11. TM #11 — Electronic Fuel Injection
12. TM #12 — Mechanical Fuel Injection
13. TM #13 — Variations of Fuel Injection Systems
14. TM #14 — Variations of Fuel Injection Systems (Continued)
15. TM #15 — Variations of Fuel Injection Systems (Continued)
16. TM #16 — Types of Fuel Filters
17. TM #17 — Series Dual Fuel Filters
18. TM #18 — Types of Fuel Lines in Diesel Fuel System

E. Job sheets

1. Job Sheet #1 — Volume and Pressure Test a Fuel Pump
2. Job Sheet #2 — Remove and Replace a Fuel Pump
3. Job Sheet #3 — Inspect Air Cleaner Service Indicator and Service Air Cleaner
4. Job Sheet #4 — Service Oil-Bath-Type Air Cleaner
5. Job Sheet #5 — Remove and Replace an In-Line Fuel Filter
6. Job Sheet #6 — Remove and Replace a Carburetor
7. Job Sheet #7 — Disassemble, Adjust, and Reassemble a Carburetor

SUGGESTED ACTIVITIES

F. Test

G. Answers to test

III. Unit references

A. Armstrong, Ivan J. *Auto Mechanics: Volume I.* Stillwater, Oklahoma: State Department of Vocational and Technical Education/Curriculum and Instructional Materials Center, 1976.

B. Foutes, William A. *Diesel Engine Mechanics.* Stillwater, Oklahoma: Mid-America Vocational Curriculum Consortium, Inc., 1977.

C. Foutes, William A. *Diesel Mechanics: Fundamentals.* Stillwater, Oklahoma: Mid-America Vocational Curriculum Consortium, Inc., 1982.

D. Hendrix, Laborn J. "Bud." *Heavy Equipment Operator Instructional Materials, Volume I.* Stillwater, Oklahoma: State Department of Vocational and Technical Education/Curriculum and Instructional Materials Center, and The Associated General Contractors of America, 1981.

FUEL SYSTEMS
UNIT III

INFORMATION SHEET

I. Terms and definitions

A. Atomization — Breaking up of a liquid into tiny particles or globules to aid evaporation

B. Atomize — To reduce to a fine spray

C. Backup wrench — Second wrench used to hold a part, such as a gas line fitting, while opposite end of fitting is loosened or tightened

D. Combustion — Act or operation of burning

E. Cross threading — Screwing any two threads together crookedly

F. Diaphragm — Flexible partition between two chambers

G. Filter — Unit containing an element of varying degrees of fineness to trap foreign particles

H. Fuel injection system — System in which pump delivers fuel to an injection nozzle that atomizes the fuel and distributes it under pressure to the combustion chamber

I. Injection nozzle — Device that distributes fuel into combustion chamber

J. Metering — Process of mixing fuel and air to correct proportions for good combustion

K. Resistor — Device made of wire or carbon that presents a resistance to current flow

L. Rheostat — Resistor for regulating current by means of variable resistance

M. Solenoid — Electromagnetic switch

N. Tang or lug — Projection

O. Torque — Turning or twisting force

P. Unit injector — Pump and injection nozzle combined into one unit

Q. Venturi — Restriction in carburetor that makes the air speed up, causing a vacuum

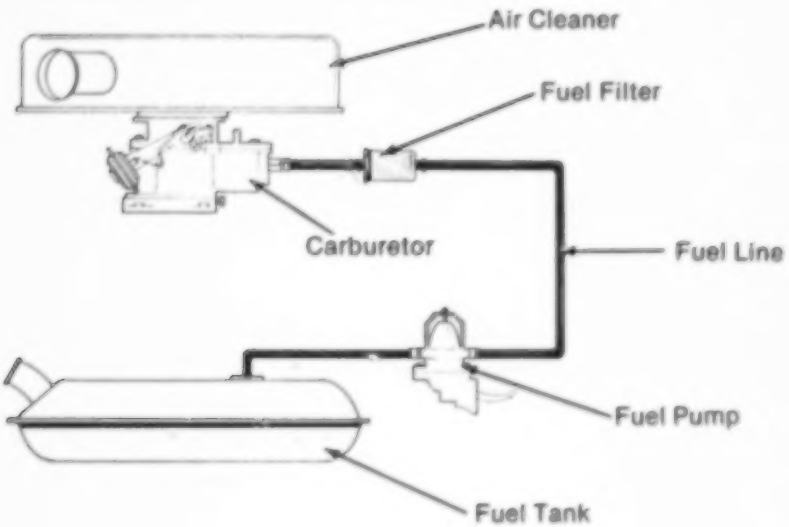
INFORMATION SHEET

II. Purpose of the fuel system — To supply a combustible mixture of air and fuel to operate engine to meet all operating requirements

III. Components of gasoline and diesel fuel systems (Figures 1 and 2; Transparencies #1 and #2)

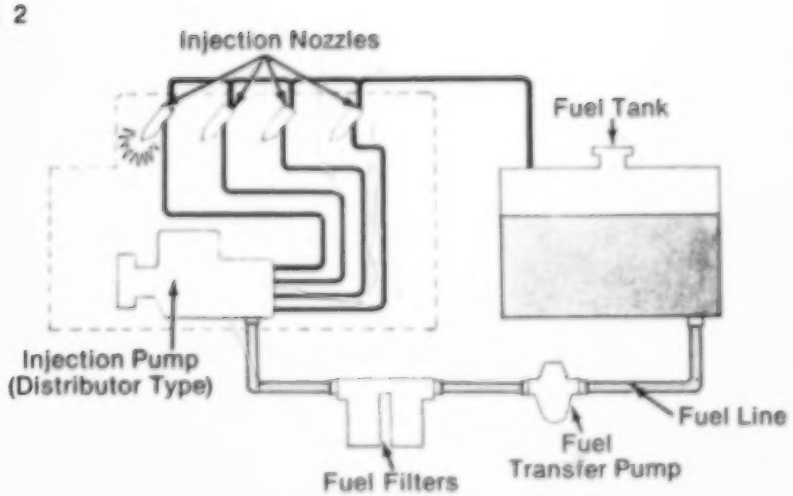
A. Gasoline

FIGURE 1



B. Diesel

FIGURE 2



INFORMATION SHEET

IV. Fuel system components and their purposes

A. Fuel tank — Stores fuel for engine use

B. Fuel pump — Pumps fuel from fuel tank through carburetor

C. Fuel filter — Prevents dirt and foreign matter from entering system

D. Fuel lines — Carry fuel from fuel tank through system

E. Carburetor — Mixes gasoline and air in proper proportion for a combustible mixture

F. Air cleaner — Filters grit and dust from air entering carburetor in gasoline engine

G. Transfer pump — Supplies fuel through filters to injection pump at low pressure

H. Injection pump — Times, measures, and delivers fuel under pressure to injection nozzles in diesel engine

I. Injection nozzle — Atomizes and sprays fuel into combustion chamber of diesel engine

V. Fuel pump operation during inlet and outlet strokes (Transparency #3)

A. Inlet stroke (Figure 3)

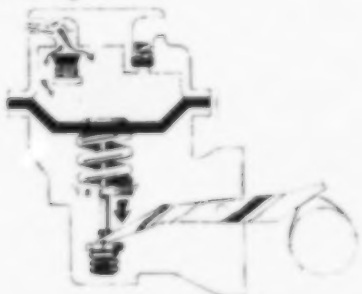
1. Diaphragm flexes downward, forming a vacuum

2. Inlet check valve opens

3. Fuel is drawn into pump

EXAMPLE:

FIGURE 3 Fuel Entering



Diaphragm Down

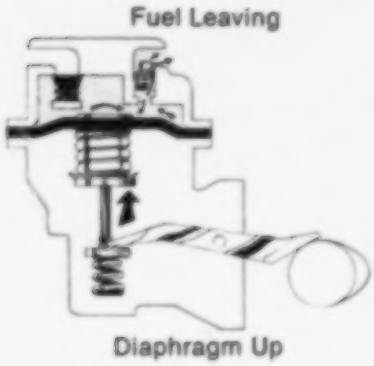
INFORMATION SHEET

B. Outlet stroke (Figure 4)

1. Diaphragm is pushed upward by return spring
2. Inlet valve is forced shut
3. Outlet valve is forced open
4. Fuel is forced out of pump

EXAMPLE:

FIGURE 4



VI. Major functions of the fuel injection system

A. Supplies correct quantity of fuel

B. Times fuel delivery

C. Controls delivery rate

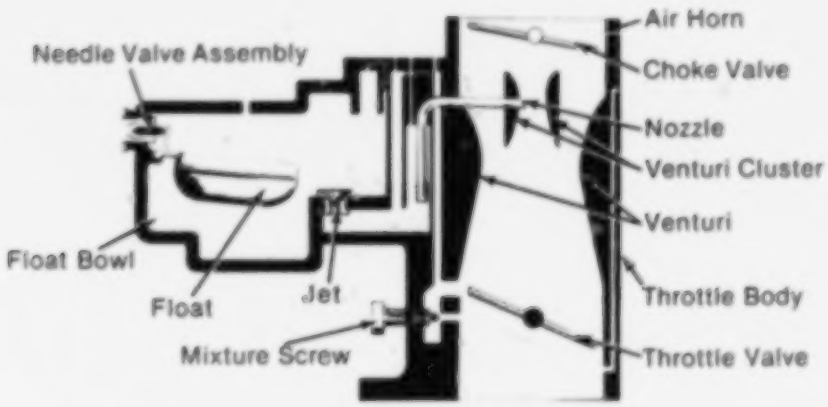
D. Atomizes fuel

E. Distributes fuel evenly throughout combustion chamber

INFORMATION SHEET

VII. Basic parts of a carburetor (Figure 5; Transparency #4)

FIGURE 5



VIII. Carburetor systems and their uses (Transparencies #5-#10)

A. Float system — Maintains a given depth of fuel in float bowl

B. Idle system — Provides fuel delivery when throttle is closed or nearly closed

C. Main metering system — Provides fuel delivery during operation with throttle partly to fully open

D. Power system — Provides extra fuel for maximum engine power to supplement main metering system

E. Accelerator pump system — Temporarily provides extra fuel necessary to overcome leanness caused by rapid throttle opening

F. Choke system — Provides a rich mixture for cold engine starting and operation

IX. Three major types of fuel injection systems

A. Common-rail system

(NOTE: The common-rail system is not suitable for high-speed, small-bore engines because it is difficult to control the small quantities of fuel injected into the cylinder at each stroke.)

INFORMATION SHEET

B. Accumulator system

(NOTE: In this system, the quantity of fuel injected per stroke can be varied.)

C. Jerk-pump system

(NOTE: Most modern diesel systems are jerk-pump systems.)

X. Variatons of fuel injection systems (Transparencies #11-#15)

A. Mechanical — Metering of fuel is controlled by mechanical devices such as cams, levers, and gears

B. Electronic — Metering of fuel is controlled by electronic devices such as solenoids, resistors, and rheostats

C. Combustion chamber injection — Fuel under pressure is injected directly into combustion chamber

(NOTE: The combustion chamber injection system is used primarily on diesel engines.)

D. Port injection — Fuel under high pressure is injected into intake air flow

(NOTE: The port injection system is most common on gasoline engines.)

E. Constant flow injection — Fuel is metered into air flow at all times; volume of fuel is varied as engine speed and load change

F. Timed injection — Fuel is metered into air flow at specific times in engine cycle as needed; length of time injector is open is varied to adjust volume of fuel as engine speed and load change

XI. Methods of injecting fuel using the pump and injection nozzle

A. Individual pump and injection nozzle for each cylinder

(NOTE: Some engine and pump manufacturers who use this system are American Bosch, Robert Bosch, and C.A.V. Sims.)

B. Combined pump and injection nozzle for each cylinder (unit injector type)

(NOTE: Some engine and pump manufacturers who use this system are General Motors Corporation and Cummins Engine Company.)

INFORMATION SHEET

C. Pumps in common housing with injection nozzle for each cylinder (in-line type)

(NOTE: Some engine and pump manufacturers who use this system are Robert Bosch, models P.E.A. and P.E.S.; American Bosch, model A.P.E.; C.A.V. Sims; and Caterpillar.)

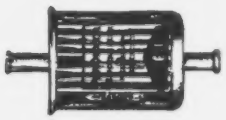
D. One pump serving injection nozzles for several cylinders (distributor type)

(NOTE: Some engine and pump manufacturers who use this system are Roosa Master, models D, DB, DC, CB, and DM; American Bosch, models P.S.B., P.S.J., and 100 series; and Robert Bosch, model EP/VA.)

XII. Types of fuel filters (Figures 6-9; Transparency #16)

A. In-line

FIGURE 6



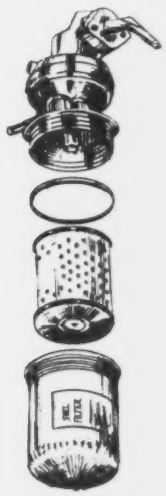
B. Bowl

FIGURE 7

INFORMATION SHEET

C. Disposable element

FIGURE 8



D. Carburetor inlet

FIGURE 9

XIII. Operation of series and parallel dual filters (Transparency #17)

A. Series — All fuel flows through one filter before flowing through other

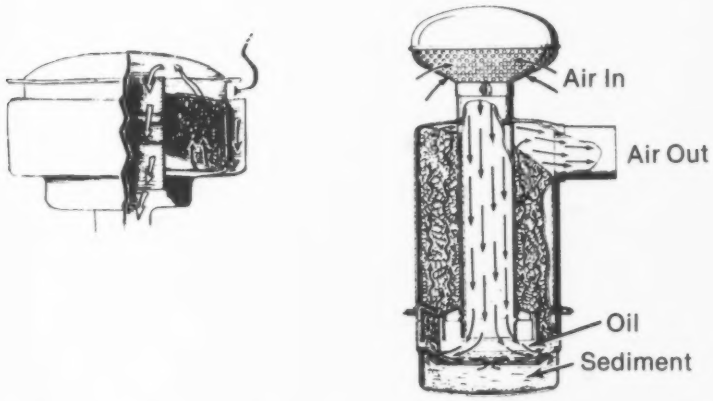
B. Parallell — Part of fuel flows through each filter

INFORMATION SHEET

XIV. Types of air cleaners (Figures 10-12)

A. Oil bath

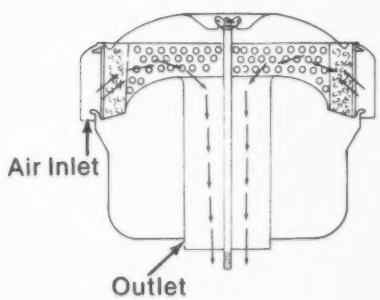
FIGURE 10



Used with permission of the Waukesha Engine Division, Dresser Industries, Inc.

B. Viscous impingement

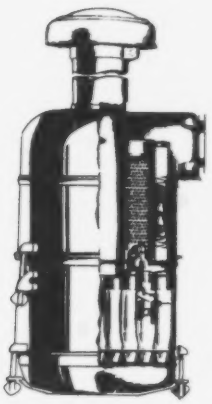
FIGURE 11



INFORMATION SHEET

C. Dry element

FIGURE 12



Used with permission of Caterpillar Tractor Co.

XV. Types of fuel lines and their purposes (Transparency #18)

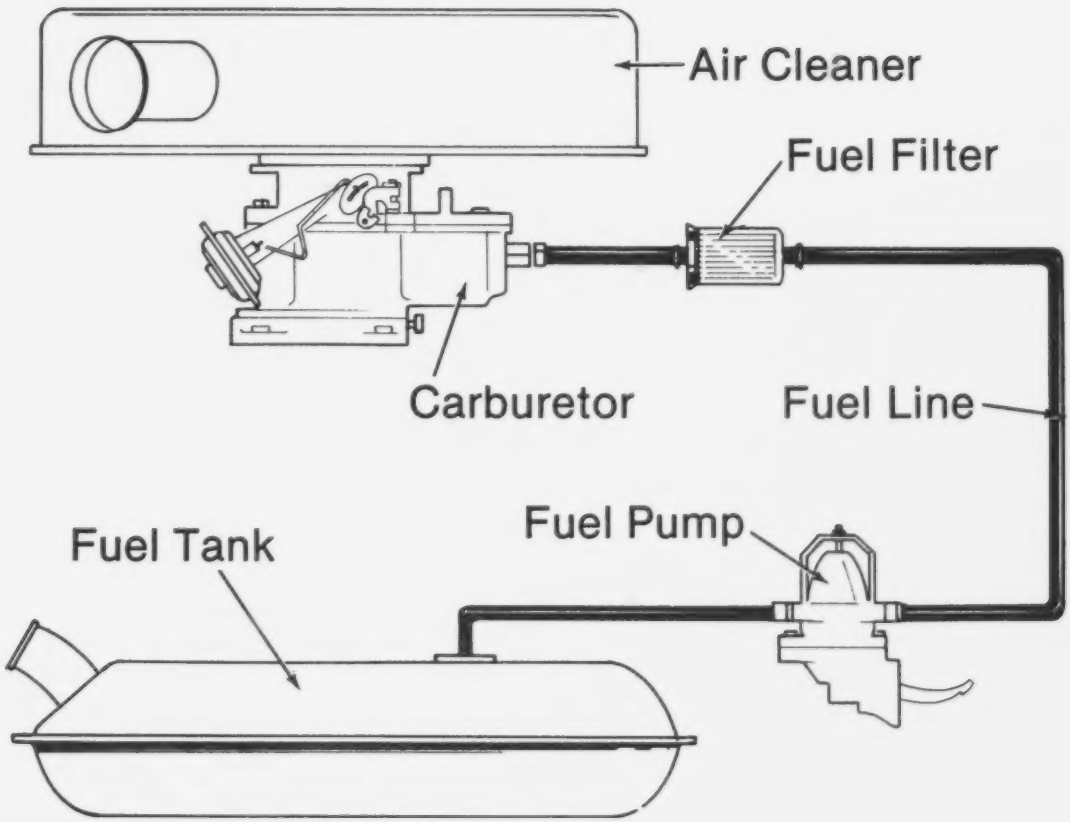
A. Heavy weight (high pressure) — Transfers fuel between injection pump and injector

B. Medium weight (low pressure) — Transfers fuel between tank and filter, and between filter and injection pump

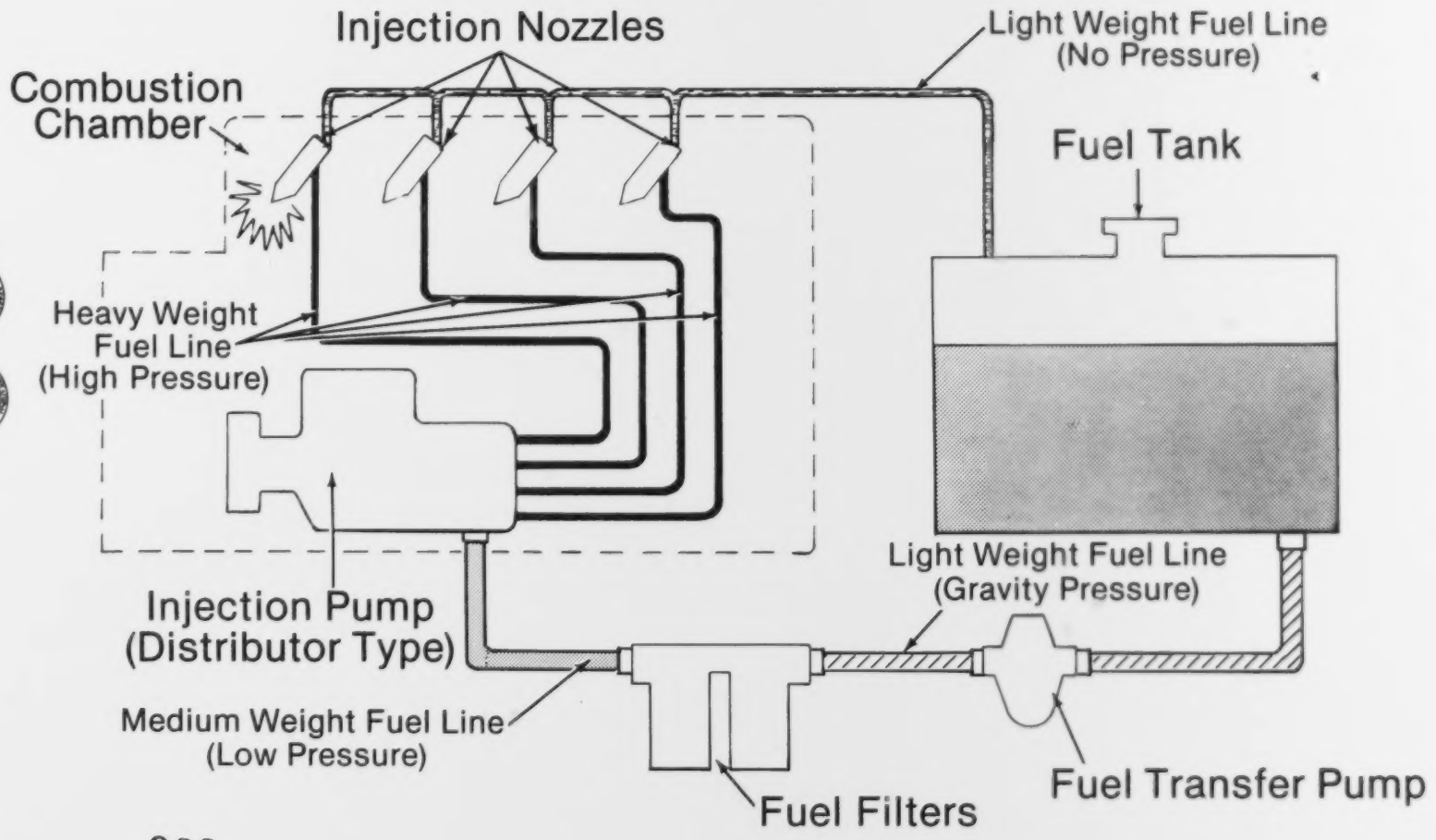
C. Light weight (no pressure) — Transfers leak-off fuel from injectors to tank or pump

D. Light weight (gravity pressure) — Transfers fuel from tank to fuel pump

Fuel System Components (Gasoline)



Fuel System Components (Diesel)



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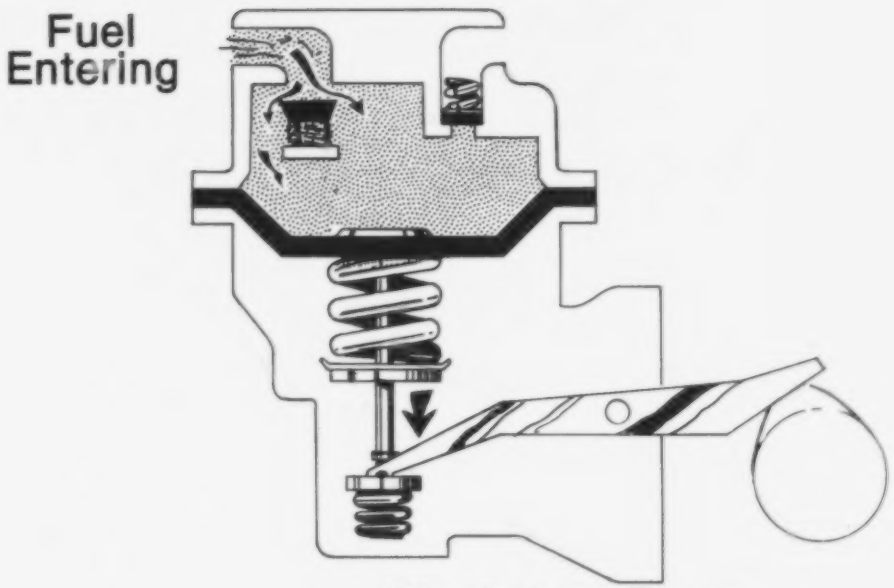
924

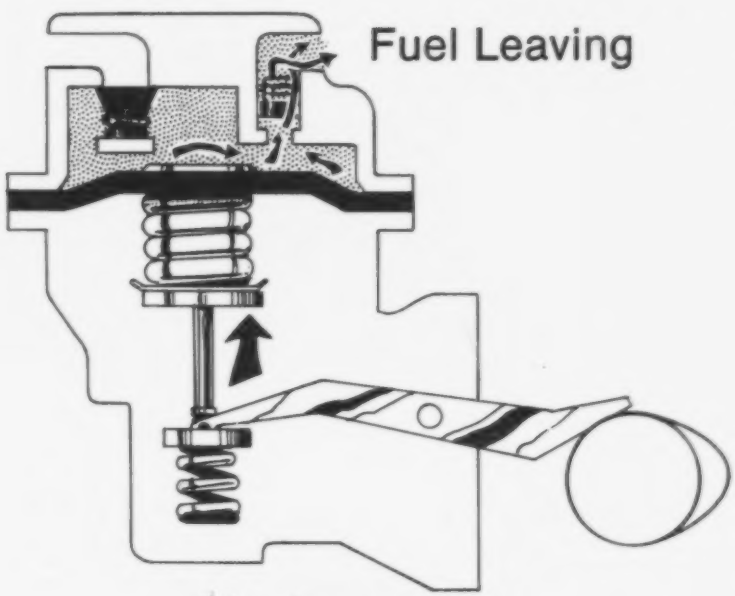
TM #2

HEM - 151-C

Fuel Pump Operation

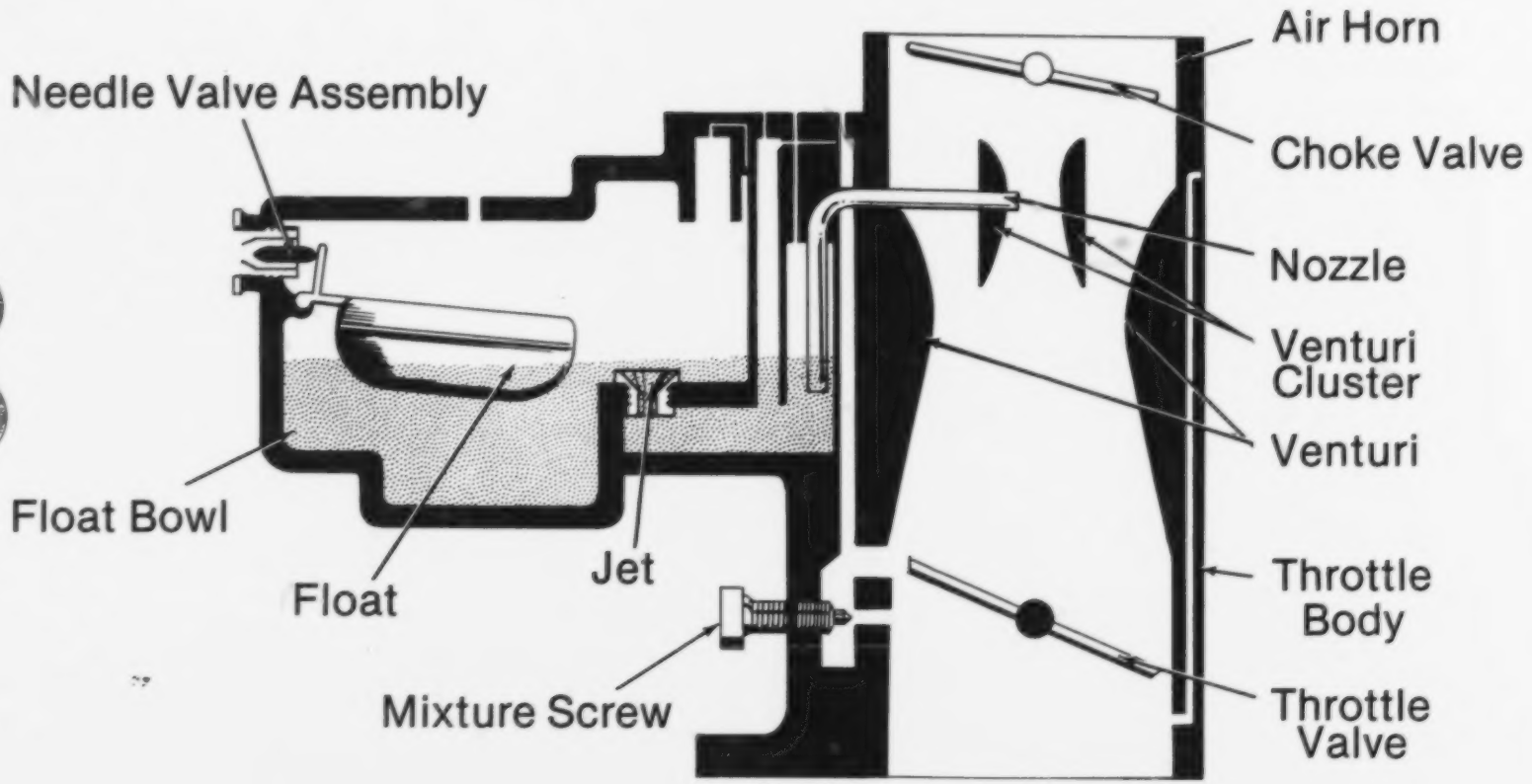


Diaphragm Down



Diaphragm Up

Parts of the Carburetor



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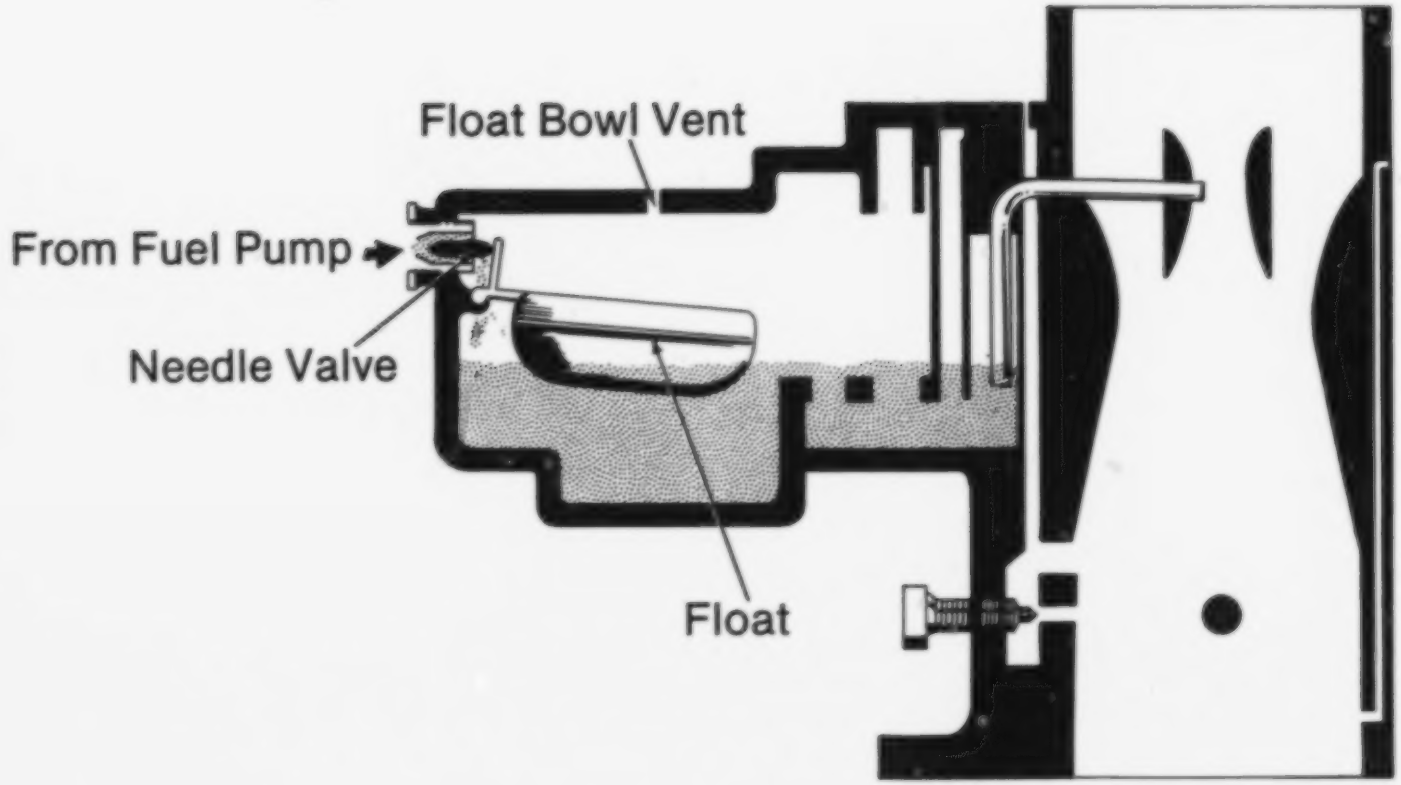
927

TM #4

HEM - 155-C

Float System



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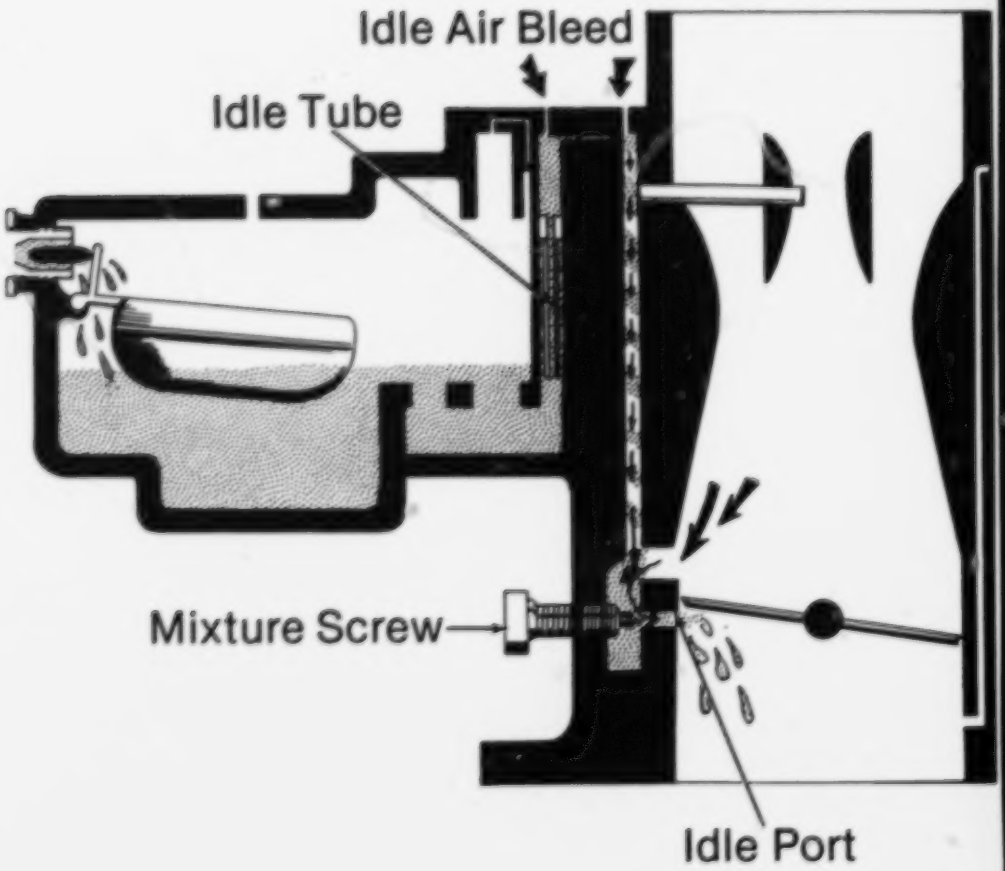
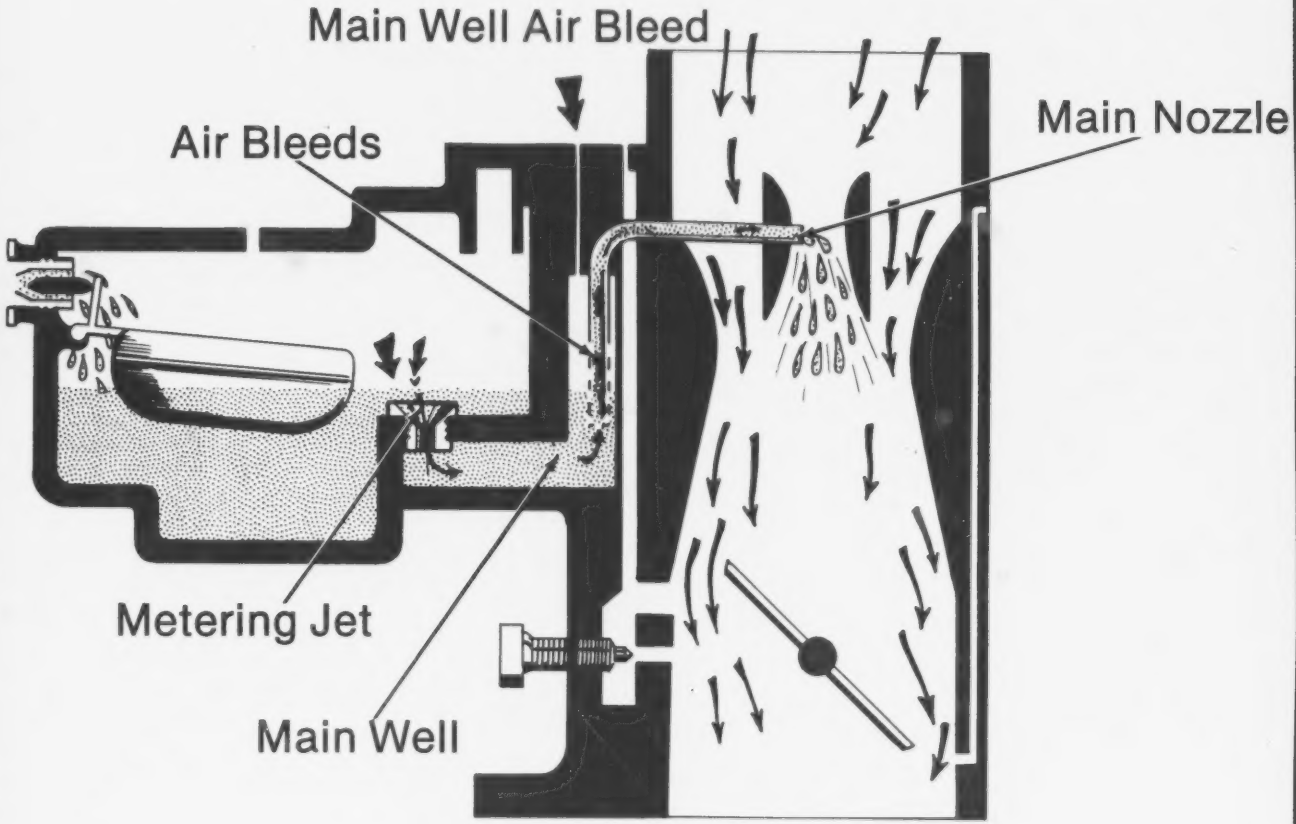
TM #5

HEM - 157-C

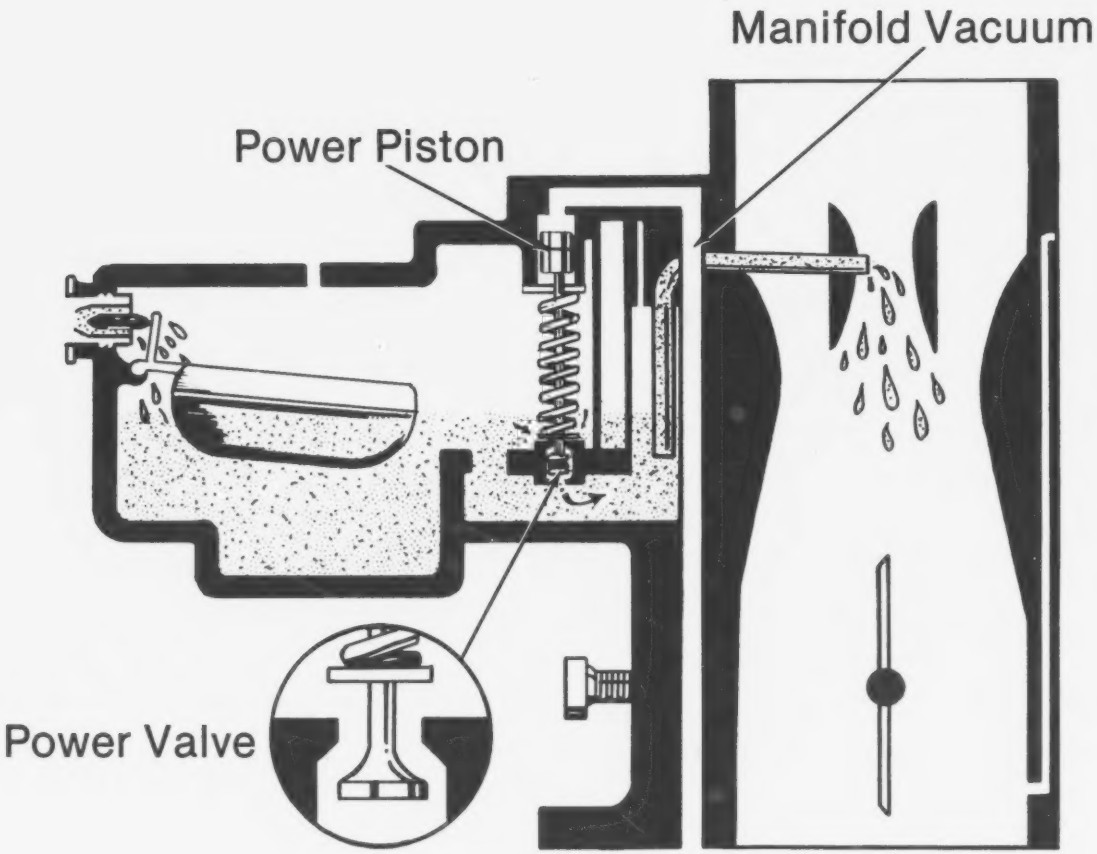
Idle System



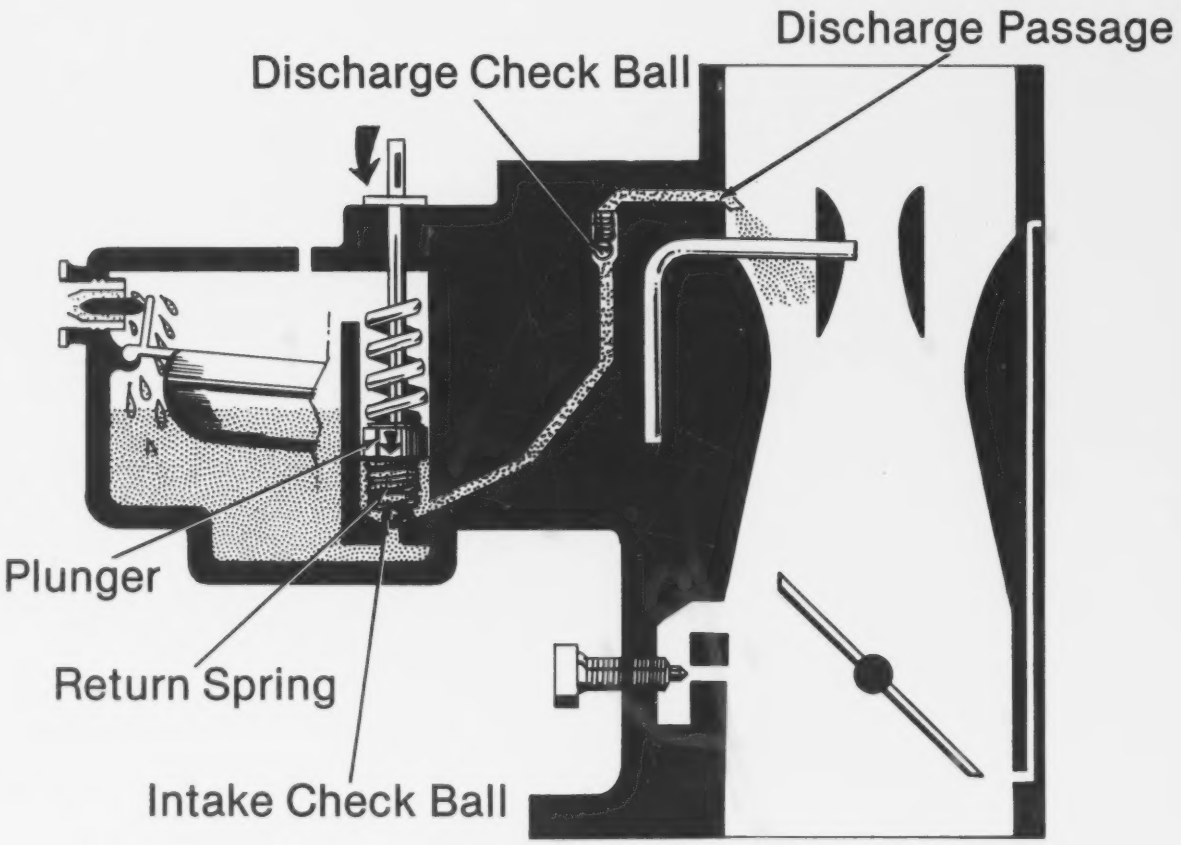
Main Metering System



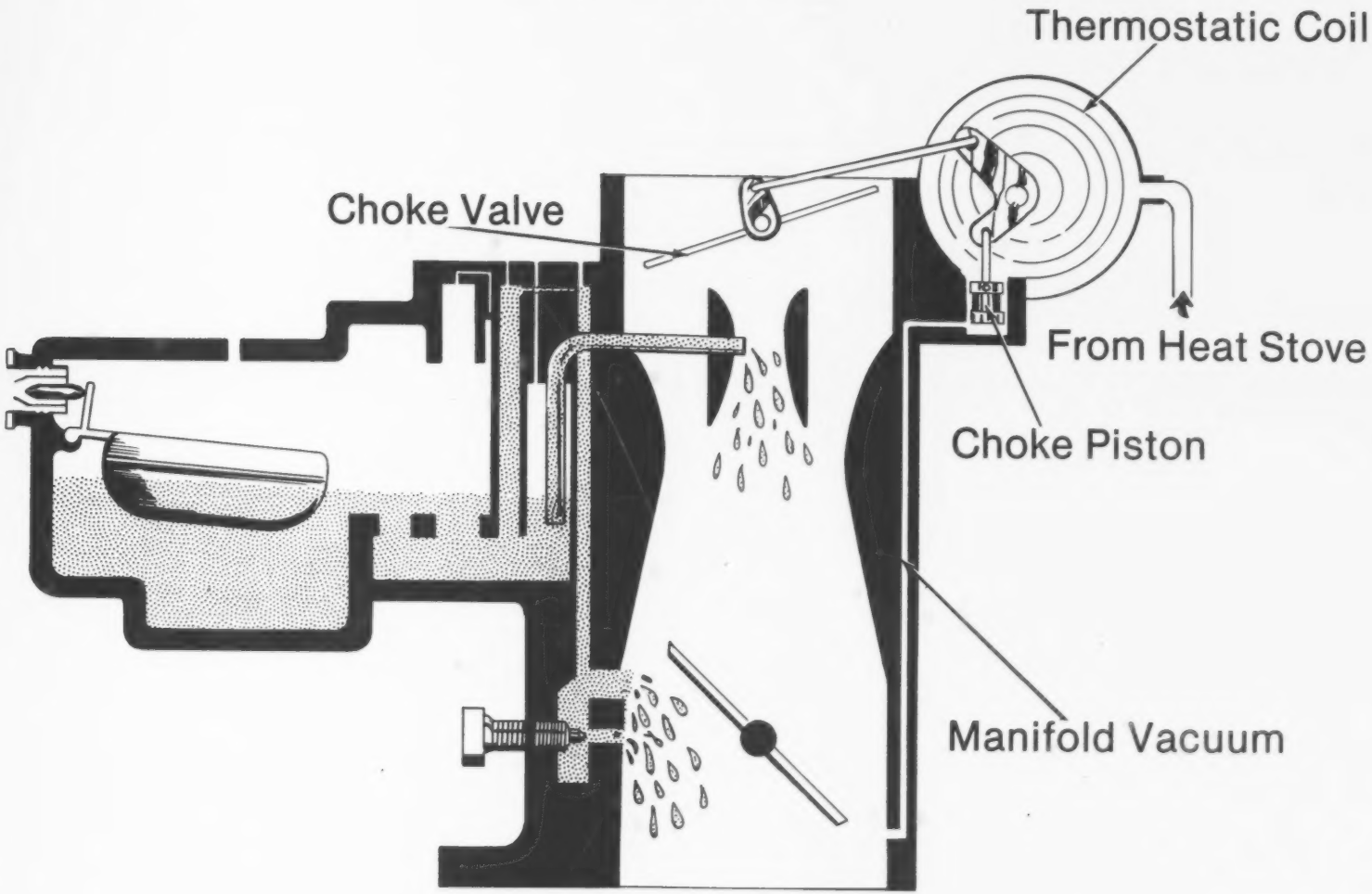
Power System



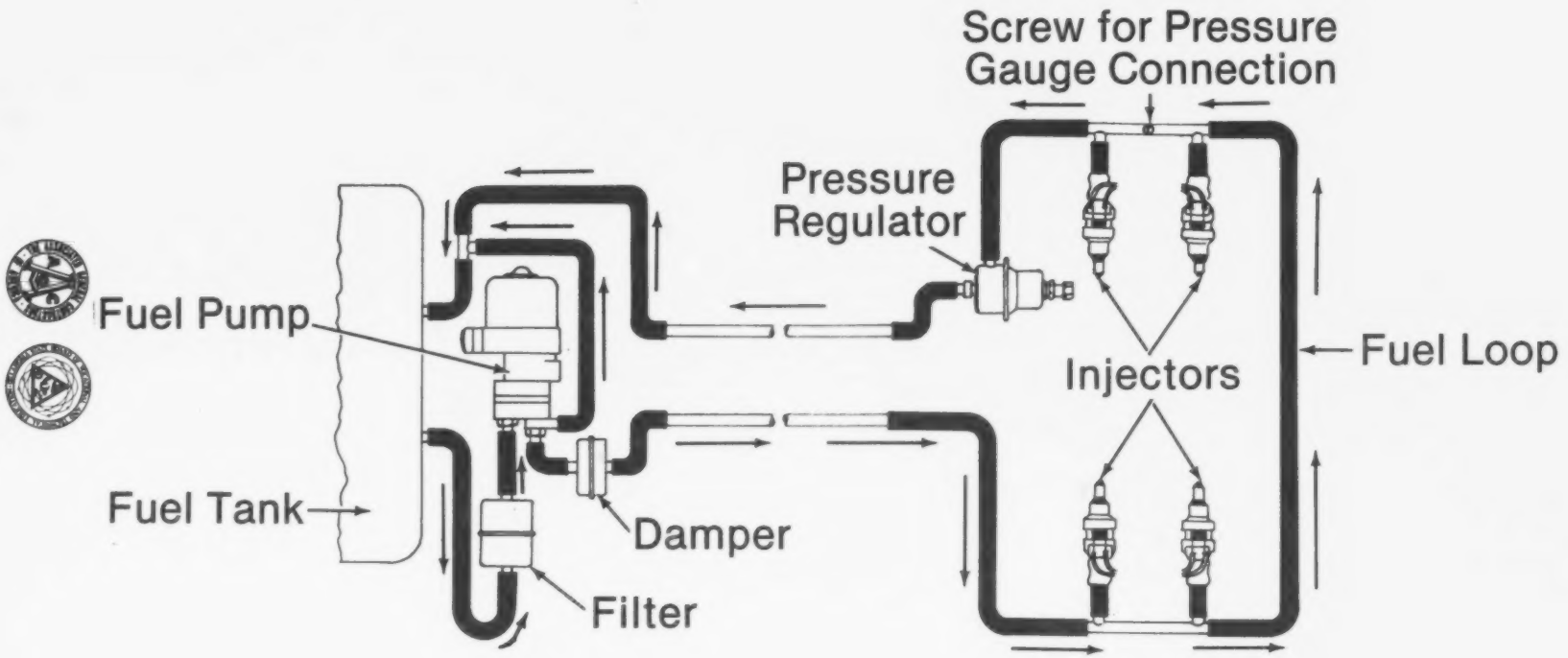
Accelerator Pump System



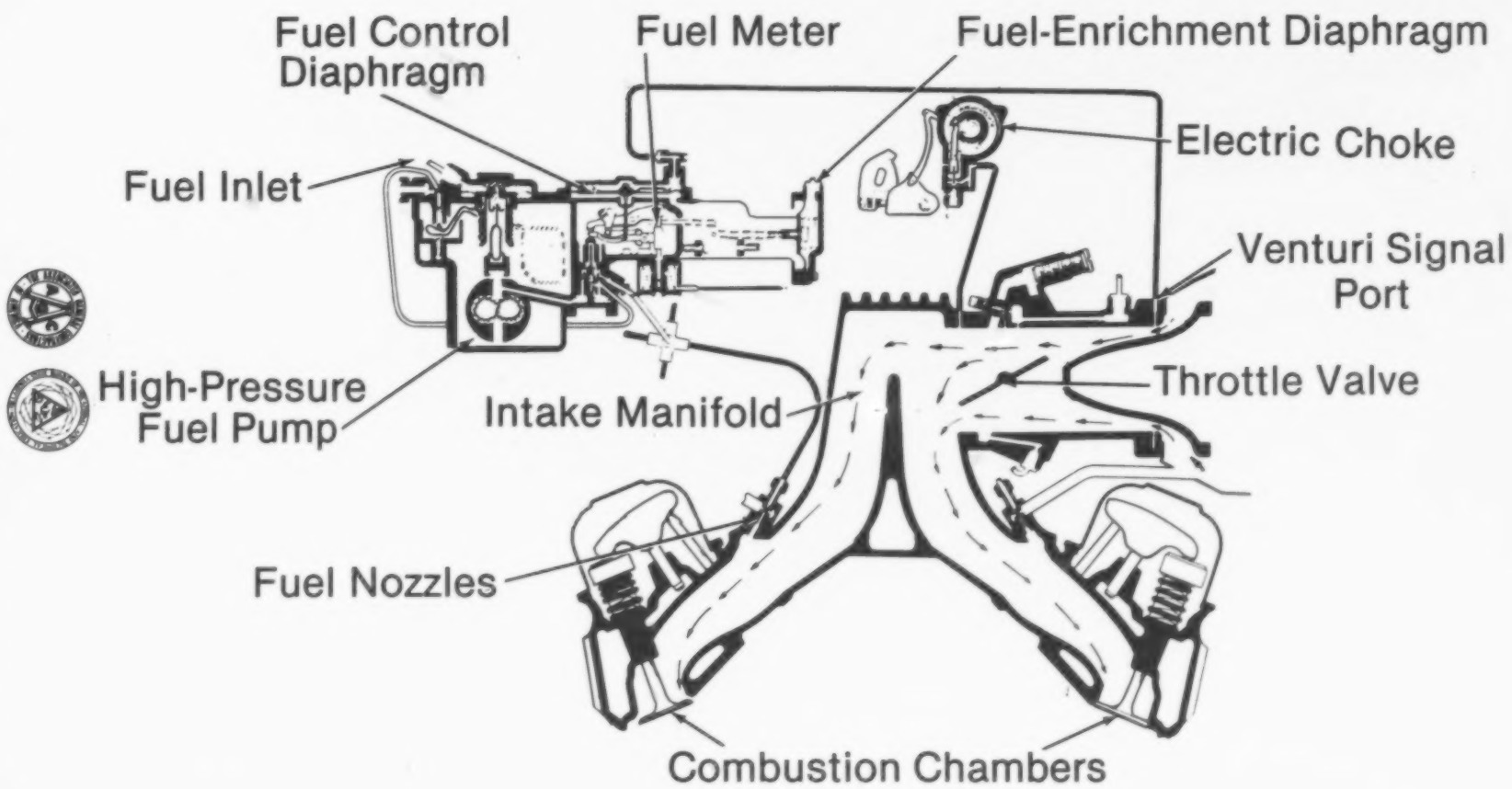
Choke System



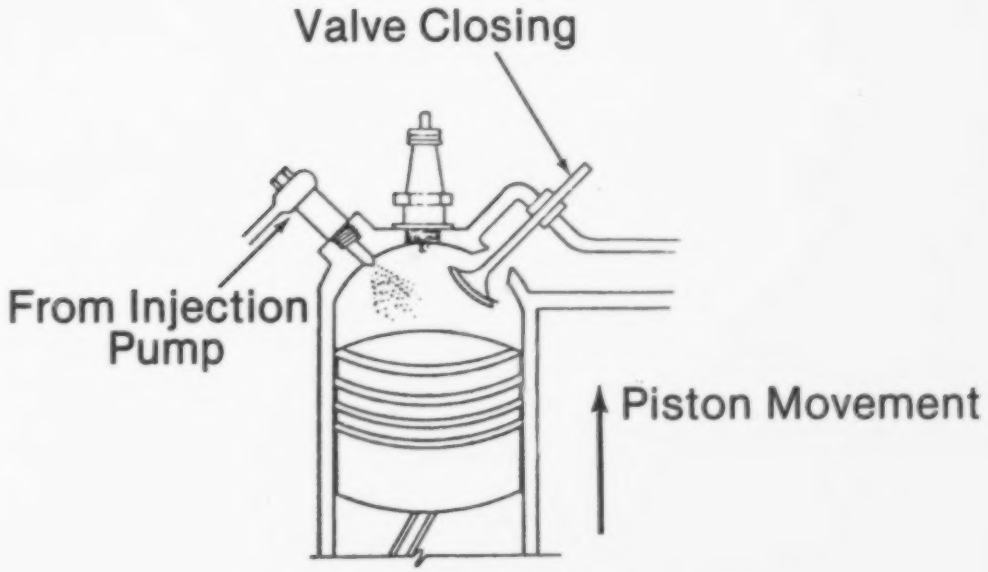
Electronic Fuel Injection



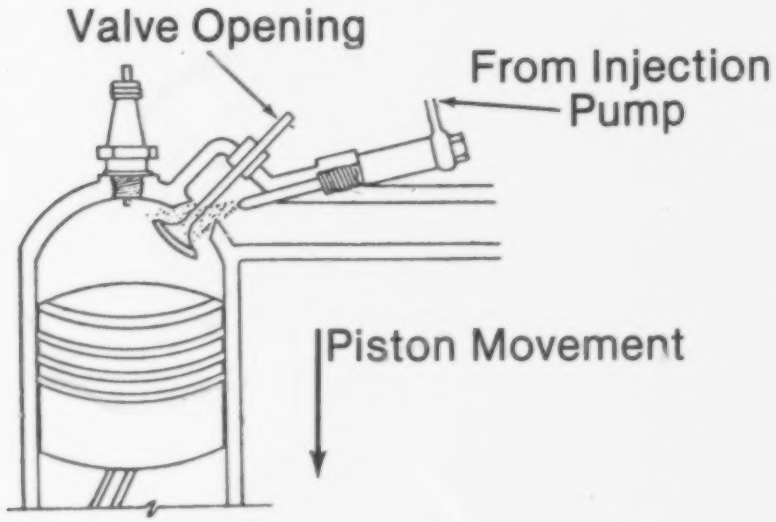
Mechanical Fuel Injection



Variations of Fuel Injection Systems

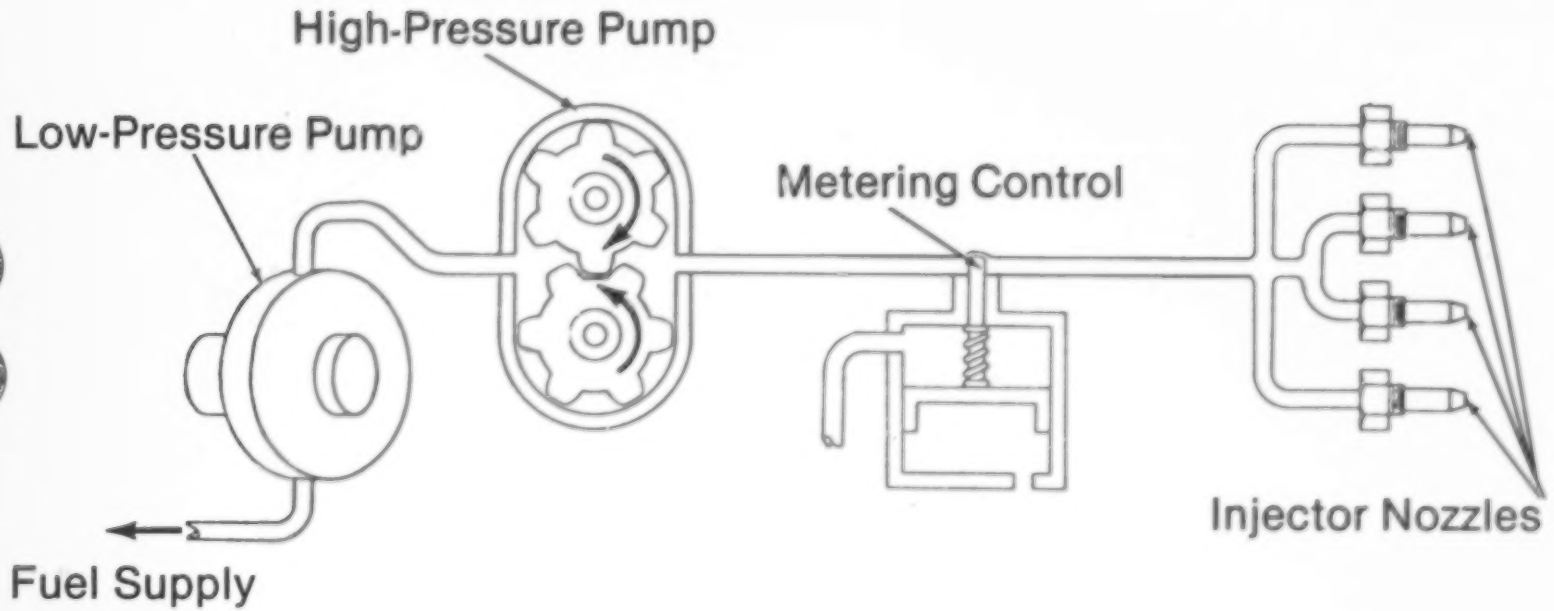


Combustion Chamber Injection



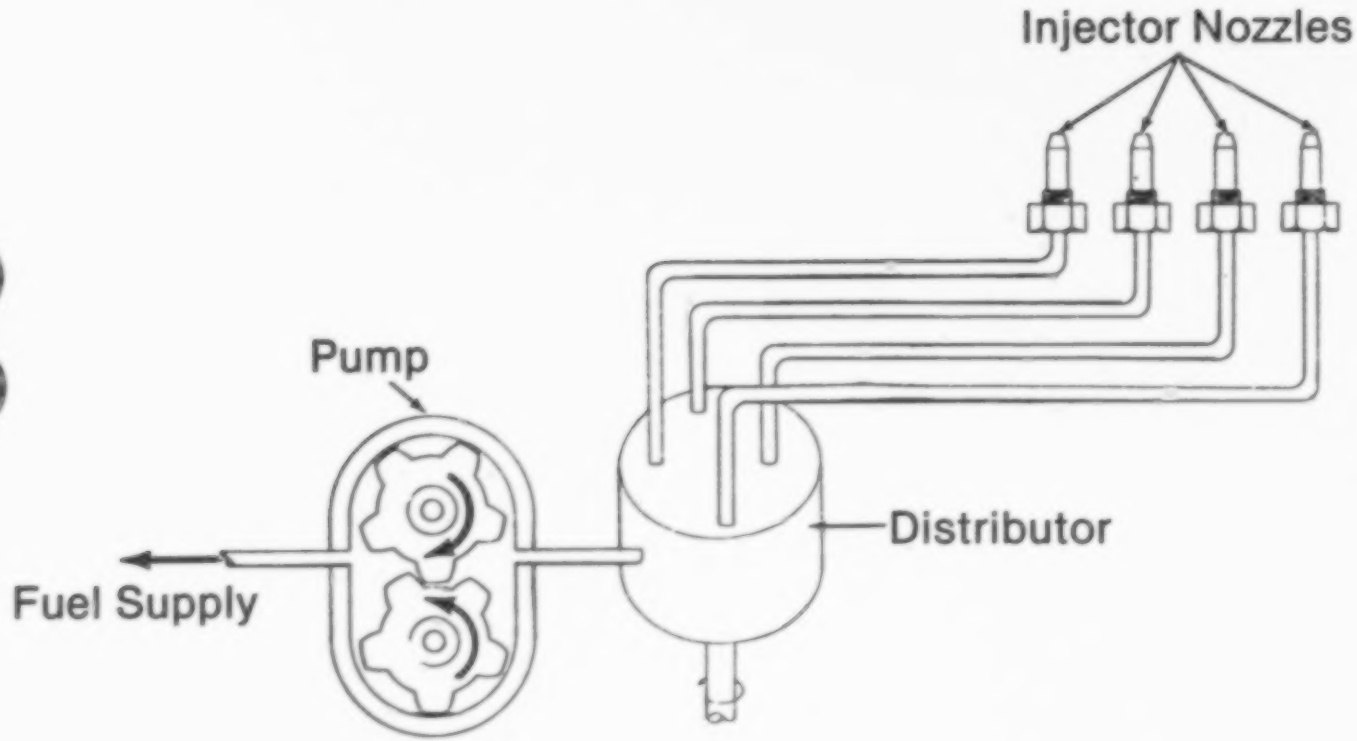
Port Injection

Variations of Fuel Injection Systems
(Continued)



Constant Flow Injection

Variations of Fuel Injection Systems
(Continued)



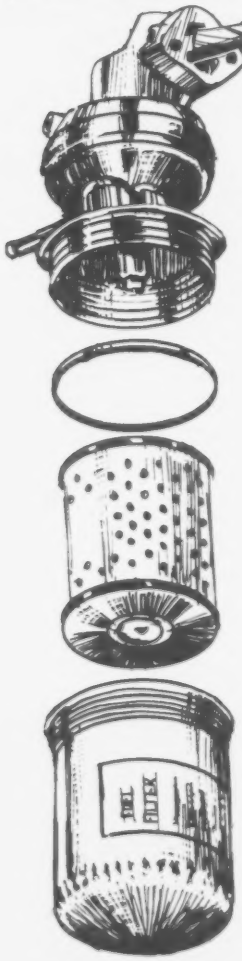
Timed Injection

Types of Fuel Filters

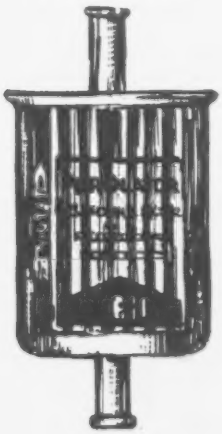
Carburetor Inlet

Bowl

Disposable Element



In-Line



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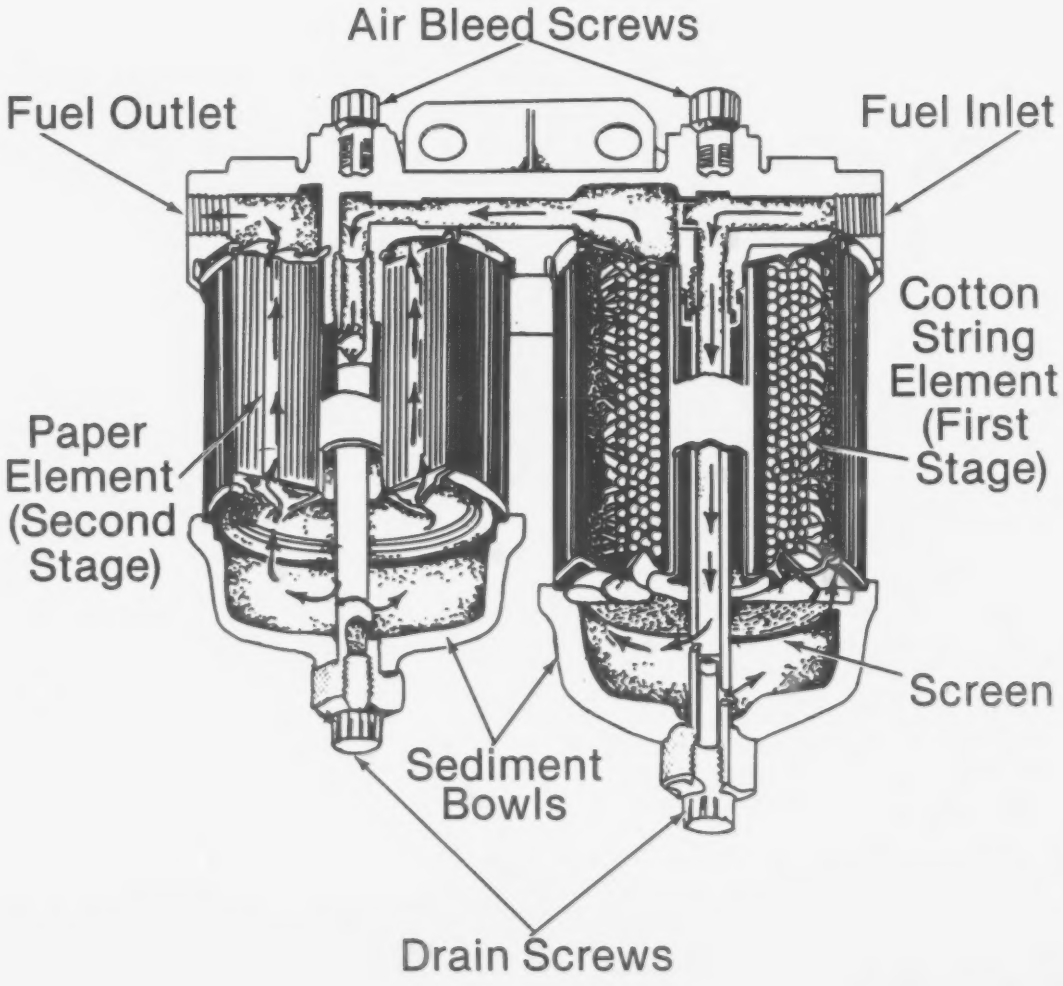
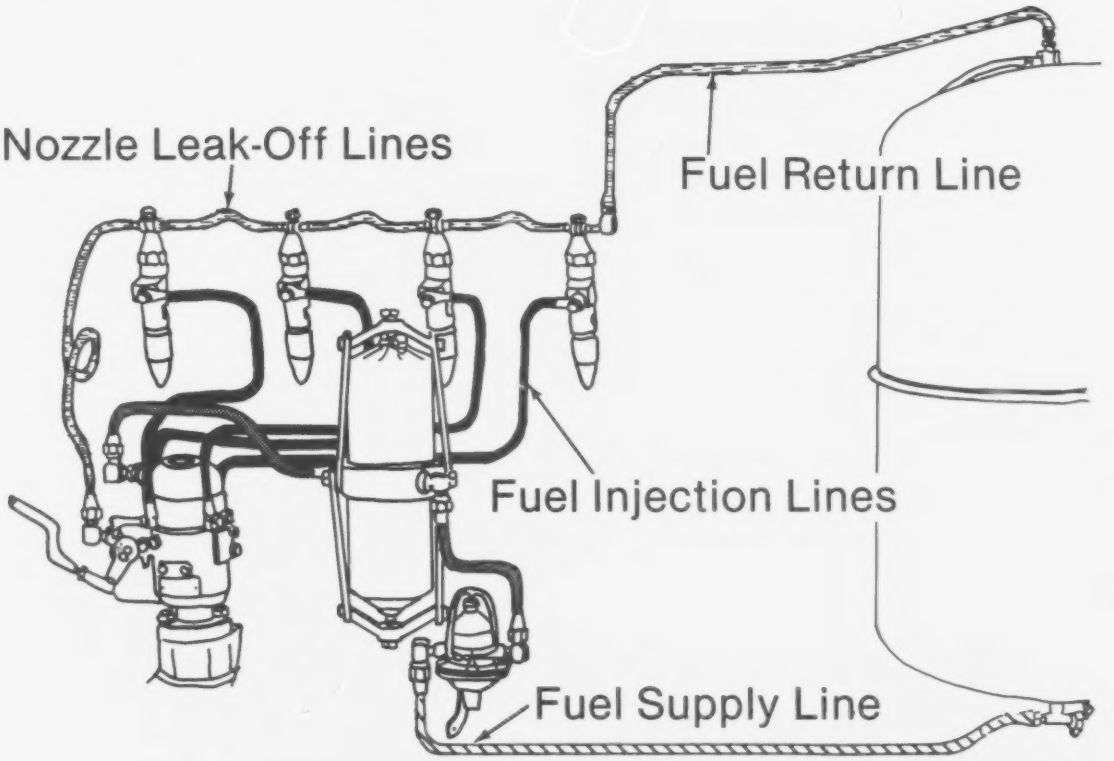
Series Dual Fuel Filters



Types of Fuel Lines in Diesel Fuel System



Heavy Weight
High Pressure

Medium Weight
Low Pressure

Light Weight
No Pressure

Light Weight
Gravity Pressure

TM #18

947

948

HEM - 183-C

FUEL SYSTEMS
UNIT III

JOB SHEET #1 — VOLUME AND PRESSURE TEST
A FUEL PUMP

I. Equipment and materials

A. Suitable fuel pump pressure and volume tester

B. Combination wrenches, 7/16 to 5/8 inch

C. Fuel line hose-clamp pliers

D. 7/16- and 9/16-inch sockets with 3/8-inch drive

E. Ratchet with 3/8-inch drive

F. 3- and 6-inch extensions with 3/8-inch drive

G. Shop towels

H. Appropriate service manual

II. Procedure

A. Tighten pump diaphragm and mounting screws before testing fuel pump

(NOTE: Inspect lines for kinks, dents, and leaks. Make sure that there is ample gas in the tank.)

B. Remove air cleaner

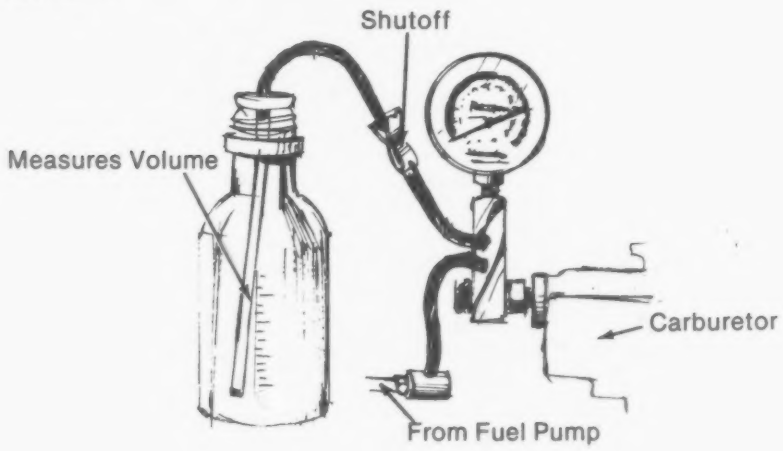
C. Disconnect main fuel line at carburetor

JOB SHEET #1

D. Connect fuel pump tester to carburetor

(NOTE: Use adapters as required. See Figure 13.)

FIGURE 13



E. Connect fuel line to fitting on fuel pump tester hose

(NOTE: Use adapters as required.)

F. Close shut-off valve on fuel discharge hose of tester

(CAUTION: Use extreme care when conducting both pressure and volume tests. A fuel pump can spray fuel a long distance. Make certain all connections are tight and that the volume hose is in the container.)

G. Start engine and adjust speed to approximately 500 revolutions per minute (rpm)

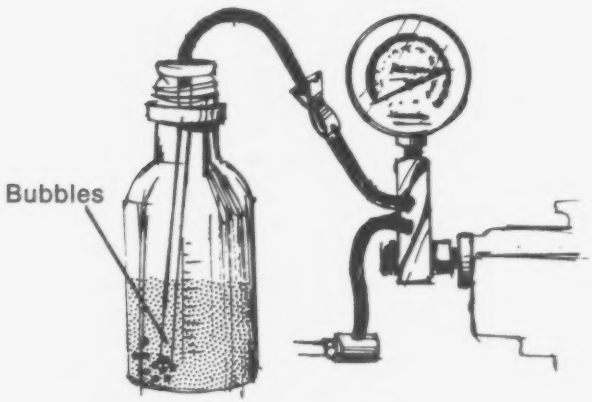
H. Make sure that volume hose is in graduated container

JOB SHEET #1

I. Open shut-off valve and observe amount of time required to pump 1 pint of fuel

(NOTE: When fuel reaches the 4-ounce level, the end of the hose should be submerged and watched for bubbles. See Figure 14.)

FIGURE 14



J. When the 1-pint level is reached, securely close shut-off valve on hose

K. With the engine still running at test speed, note gauge reading on fuel pump tester

L. Shut off engine

M. Compare volume and pressure test readings with vehicle manufacturer's specifications

(NOTE: Be sure to properly dispose of fuel to avoid fire hazard.)

N. Remove fuel pump tester from engine

O. Connect fuel line to carburetor

(NOTE: Use a backup wrench to avoid twisting the fuel line.)

P. Tighten all lines securely

Q. Install air cleaner

JOB SHEET #1

R. Start engine

S. Check for leaks

(CAUTION: Secure all fuel lines and double-check tightness of connections to prevent fuel leaks.)

T. Clean work area; clean and put away all tools and equipment

FUEL SYSTEMS
UNIT III

JOB SHEET #2 — REMOVE AND REPLACE A FUEL PUMP

I. Equipment and materials

A. Combination wrenches, 7/16- and 5/8-inch

B. Fuel line hose-clamp pliers

C. 7/16- and 9/16-inch sockets with 3/8-inch drive

D. Ratchet with 3/8-inch drive

E. 3- and 6-inch extensions with 3/8-inch drive

F. Shop towels

G. Gasket sealer

H. Appropriate service manual

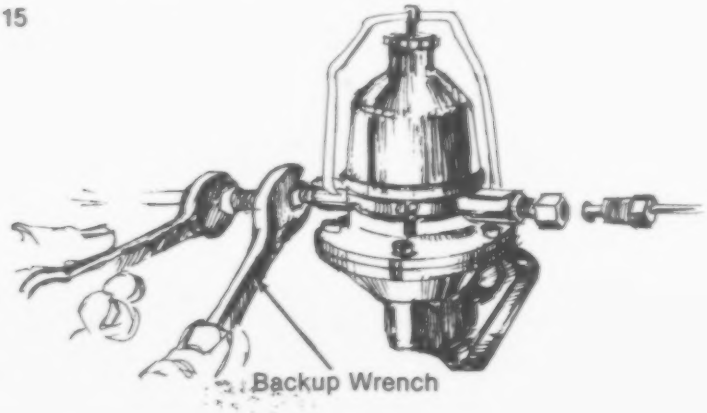
II. Procedure

A. Disconnect fuel lines from fuel pump

(NOTE: Use a backup wrench on all fuel lines and fittings to avoid twisting the lines. See Figure 15.)

(CAUTION: Make sure fuel is not flowing from the inlet fuel line. If fuel is flowing, it must be plugged to prevent danger of fire.)

FIGURE 15



JOB SHEET #2

B. Remove other vacuum or return lines if required

C. Remove fasteners that attach fuel pump to engine

D. Remove fuel pump

(NOTE: Observe the shape and location of the fuel pump arm. Check the location of the fuel pump pushrod if used.)

E. Check fuel pump mounting surface on engine

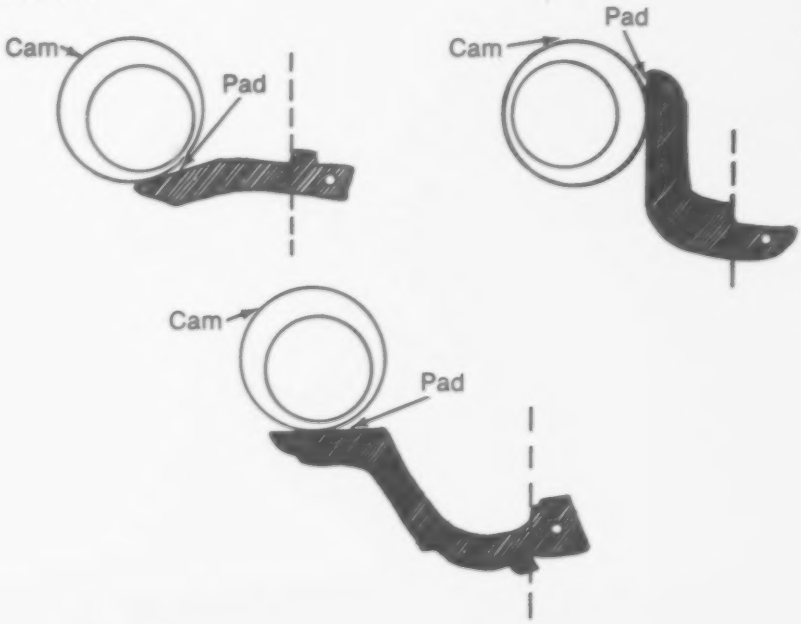
F. Coat mounting surfaces of fuel pump and engine with gasket sealer

G. Install a new mounting gasket on fuel pump

(NOTE: Study the shape of the rocker arm, and note the positioning of the pad.)

H. Check location of cam or pushrod and install pump to make correct contact (Figure 16)

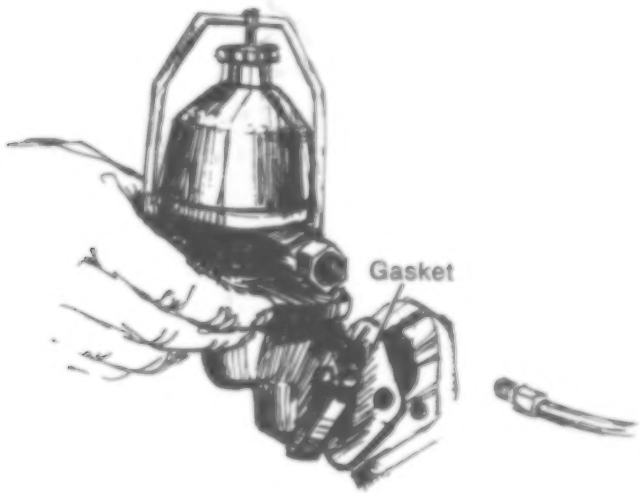
FIGURE 16



JOB SHEET #2

I. Shove pump inward until mounting flange is against mounting pad (Figure 17)

FIGURE 17



J. Install fasteners and torque to specifications

(NOTE: Make sure that the pump is free to move against the mounting pad before tightening the bolts.)

K. Attach fuel lines, hoses, or other lines as required

(NOTE: Fittings must align to prevent cross-threading.)

L. Tighten fuel lines securely

(NOTE: To prevent fuel line damage, hold pump fitting with one wrench while tightening flare nut with the other.)

M. Start engine

N. Check for leaks

(CAUTION: Secure all fuel lines and double-check tightness of connections to prevent fuel leaks.)

O. Clean work area; clean and put away all tools and equipment

FUEL SYSTEMS
UNIT III

JOB SHEET #3 — INSPECT AIR CLEANER SERVICE INDICATOR AND SERVICE AIR CLEANER

I. Equipment and materials

- A. Compressed air
- B. Safety glasses
- C. Cleaning solvents
- D. Nonsudsing detergent
- E. Cleaning brush
- F. Shop towels
- G. Screwdriver
- H. Hot water supply
- I. Appropriate service manual

II. Procedure

- A. Check air cleaner service indicator

  (NOTE: When element is clean, the indicator will show a yellow band. When accumulated dust causes air flow restriction, the indicator will show a red band.)

- B. Clean indicator
- C. Clean intake screen if air cleaner is so equipped
- D. Remove and clean rain cap

  (NOTE: Rain cap may be cleaned by back-blowing with compressed air. Clean oil and sticky materials from cap by washing in clean, hot water containing a small amount of nonsudsing detergent.)

  (CAUTION: Always wear safety glasses when using compressed air.)

- E. Loosen retaining clamp and remove dust cup (Figure 18)

FIGURE 18

JOB SHEET #3

F. Remove baffle from inside the cup

G. Remove wing nut, washer, and seal

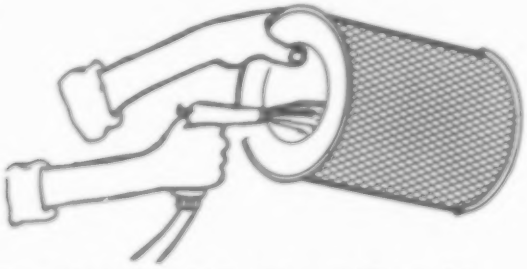
H. Pull out element

I. Clean element with a controlled stream of air (Figure 19)

(CAUTION: Always wear safety glasses when using compressed air.)

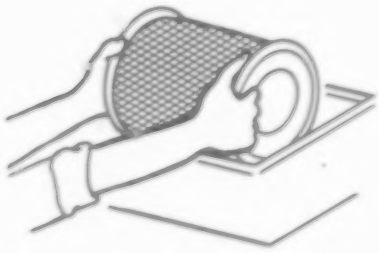
(NOTE: If back-blowing does not clean element sufficiently, it will be necessary to wash or replace element.)

FIGURE 19



J. Wash filter using a good filter cleaner (Figure 20)

FIGURE 20



K. Rinse filter thoroughly in clear water (Figure 21)

(CAUTION: Do not use a hard stream from a hose. Such force can damage filter.)

FIGURE 21

JOB SHEET #3

L. Set filter aside to dry while cleaning filter case and other parts

(NOTE: Inspect element after it is clean and dry.)

M. Rotate element in front of a light bulb

(NOTE: This method will show pinholes or other damage to element.)

N. Visually check rubber gasket for damage, and check for dents in the covering

O. Reinstall element in its case

P. Reinstall seal, washer, and wing nut

Q. Reinstall baffle in dust cup

R. Reinstall dust cup

S. Tighten retaining clamp

T. Reinstall rain cap and tighten retaining clamp

U. Clean work area; clean and put away all tools and equipment

FUEL SYSTEMS
UNIT III

JOB SHEET #4 — SERVICE OIL-BATH-TYPE AIR CLEANER

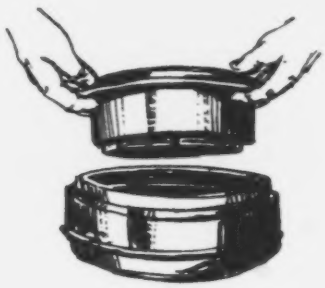
I. Equipment and materials

- A. Cleaning solvent
- B. Light weight oil
- C. Motor oil
- D. Shop towels
- E. Appropriate service manual

II. Procedure

- A. Remove wing nut
- B. Lift out gauze air strainer (Figure 22)

FIGURE 22



JOB SHEET #4

C. Rinse air strainer in cleaning solvent (Figure 23)

FIGURE 23

D. Shake excessive solvent from air strainer

E. Saturate air strainer gauze with light oil and allow excess to drip off

F. Pour out oil in lower body; discard

G. Wash dirt and grit out of lower body with cleaning solvent (Figure 24)

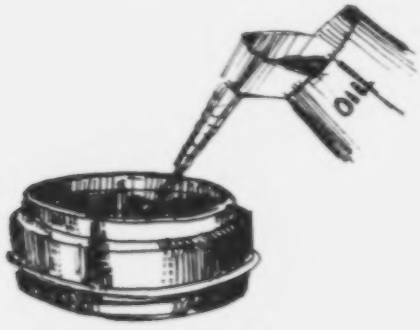
FIGURE 24

JOB SHEET #4

H. Fill lower body to correct level with fresh engine oil of correct SAE specification (Figure 25)

(NOTE: Do not overfill.)

FIGURE 25



I. Place units together and install wing nut

(NOTE: Make sure that gasket is in place between the air strainer and lower body.)

J. Tighten wing nut securely

K. Clean filter body and cover before reinstalling

(NOTE: Make certain that the gasket between the air cleaner and carburetor is in good condition and is in place; replace if necessary.)

L. Reinstall air cleaner body

(NOTE: Make sure that the air cleaner faces in the correct direction. If a locating tang or lug is present, make sure that it engages properly.)

M. Tighten air cleaner wing nut

(NOTE: Avoid overtightening; ovetightening can cause improper operation of the choke.)

N. Install other hoses or vacuum lines as required

O. Clean work area; clean and put away all tools and equipment

FUEL SYSTEMS
UNIT III

JOB SHEET #5 — REMOVE AND REPLACE AN IN-LINE FUEL FILTER

I. Equipment and materials

- A. Screwdriver or hose-clamp pliers (depending on type of clamps)
- B. New filter, clamps, and hose sections
- C. Shop towels
- D. Appropriate service manual

II. Procedure

- A. Place shop towels under filter to absorb fuel when lines are removed
- B. Remove clamp from one side of metal fuel line, leaving small section of rubber hose on filter
- C. Remove clamp from line on other side of filter, again leaving small section of rubber hose on filter
- D. Remove old filter
- E. Place new sections of hose on both sides of new filter
- F. Place new clamps on hose; tighten
- G. Install new filter on fuel line and tighten clamps
- H. Remove shop towels from under filter and wipe everything clean
- J. Clean work area; clean and put away all tools and equipment

FUEL SYSTEMS
UNIT III

JOB SHEET #6 — REMOVE AND REPLACE A CARBURETOR

I. Equipment and materials

A. Combination wrenches, 7/16- and 5/8-inch

B. 7/16- and 5/8-inch sockets with 3/8-inch drive

C. Ratchet with 3/8-inch drive

D. 6-inch extension with 3/8-inch drive

E. 10-inch adjustable wrench

F. Screwdriver

G. Fuel line hose-clamp pliers

H. New carburetor

I. Base gasket

J. Shop towels

K. Appropriate service manual

II. Procedure

A. Remove air cleaner

B. Disconnect fuel line

(NOTE: Use a backup wrench to avoid twisting the fuel line.)

C. Disconnect vacuum lines if necessary

D. Disconnect throttle linkage

E. Disconnect choke control cable on manual choke if required

F. Disconnect heat tube or automatic choke linkage as required

G. Remove any accessories that will interfere with removal of carburetor

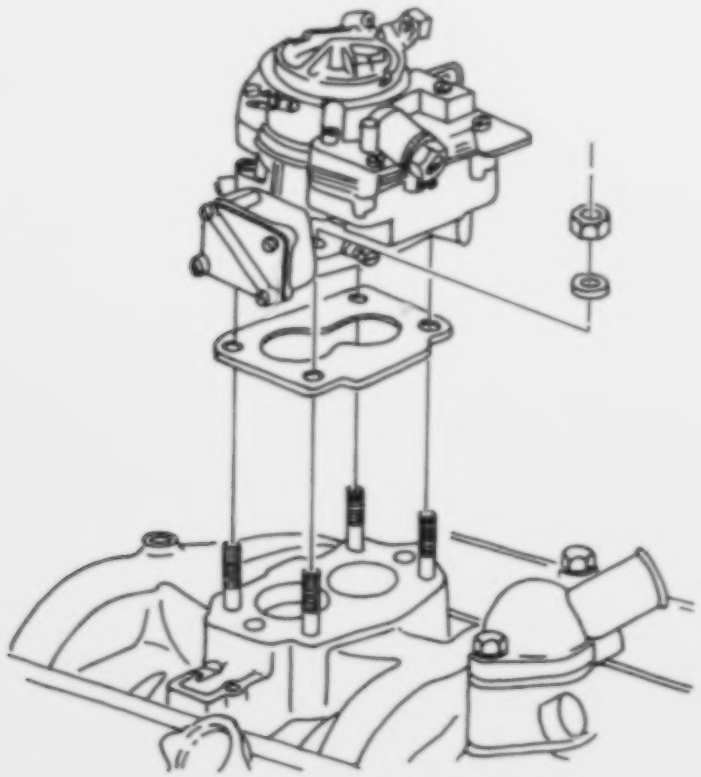
H. Remove fasteners that hold carburetor on manifold

JOB SHEET #6

I. Remove carburetor (Figure 26)

(CAUTION: Use extreme care to avoid dropping bolts, nuts, or any foreign material into manifold opening when carburetor is removed.)

FIGURE 26



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J. Remove old carburetor base gasket

K. Clean gasket mounting surface

(NOTE: Cover the manifold opening with a shop towel during cleaning.)

L. Install new carburetor base gasket

M. Place carburetor in correct position; start fasteners

JOB SHEET #6

N. Tighten and torque carburetor fasteners

O. Reinstall vacuum lines if required

P. Reinstall throttle linkage

Q. Connect automatic choke linkage or heat tube if required

R. Connect fuel line to carburetor

(NOTE: Use caution to avoid cross-threading.)

S. Tighten fuel line securely

(NOTE: Use a backup wrench to avoid fuel line twisting.)

T. Check to make sure that all connections and accessories are secure

U. Start the engine

V. Check for leaks

(CAUTION: Secure all fuel lines and double-check tightness of connections to prevent fuel leaks.)

W. Make idle air mixture and idle speed adjustments if required

X. Reinstall air cleaner

(NOTE: Make sure that it is securely in place and positioned correctly.)

Y. Clean work area; clean and put away all tools and equipment

FUEL SYSTEMS
UNIT III

JOB SHEET #7 — DISASSEMBLE, ADJUST, AND REASSEMBLE A CARBURETOR

I. Equipment and materials

- A. Screwdrivers, assorted sizes
- B. Pliers
- C. Phillips screwdriver
- D. 10-inch adjustable wrench
- E. Needlenose pliers
- F. Suitable carburetor adjusting tools
- G. Rochester 2GC carburetor
- H. Cleaning solvent
- I. Shop towels
- J. Appropriate service manual
- K. Safety glasses

II. Procedure

- A. Disassemble air horn

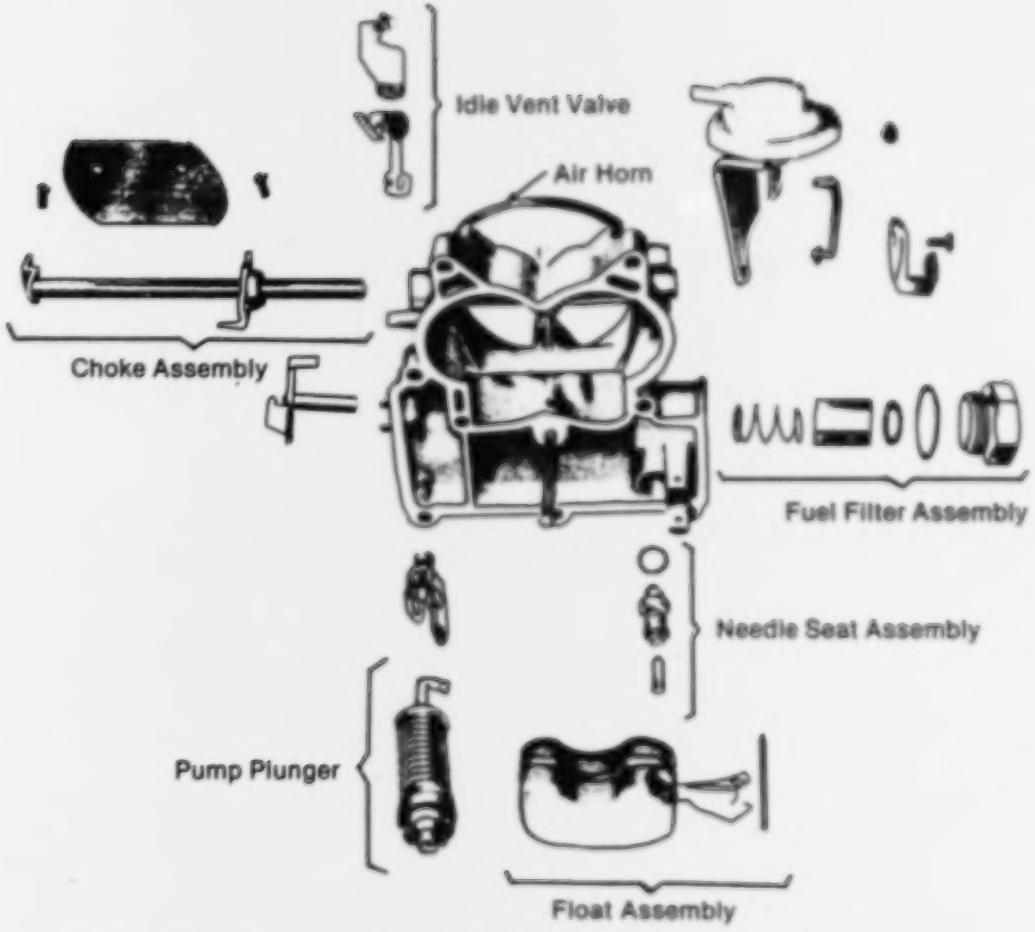
  (NOTE: Refer to Figure 27 on the following page.)

  1. Remove fuel inlet fitting, gasket, and filter
  2. Remove idle vent valve retaining screw shield and vent
  3. Remove retainer clips from choke and unloader rod
  4. Remove choke and unloader rod
  5. Remove spring choke from upper end of pump rod at pump lever
  6. Disconnect upper end of pump rod
  7. Remove air horn attaching screws
  8. Remove air horn

JOB SHEET #7

9. Invert air horn
10. Remove float hinge pin and float
11. Remove needle assembly

FIGURE 27



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JOB SHEET #7

12. Remove needle seat and gasket
13. Remove retainer from pump plunger shaft; remove pump plunger
14. Remove air horn gasket
15. Remove choke valve or shaft if required

B. Disassemble float bowl

(NOTE: Refer to Figure 28 on the following page.)

1. Remove pump plunger return spring and check ball as required
2. Remove main metering jets and power valve
3. Remove venturi cluster attaching screws and venturi cluster
4. Remove pump discharge spring guide, spring, and ball
5. Invert fuel bowl
6. Remove throttle body attaching screws
7. Remove throttle body and gasket

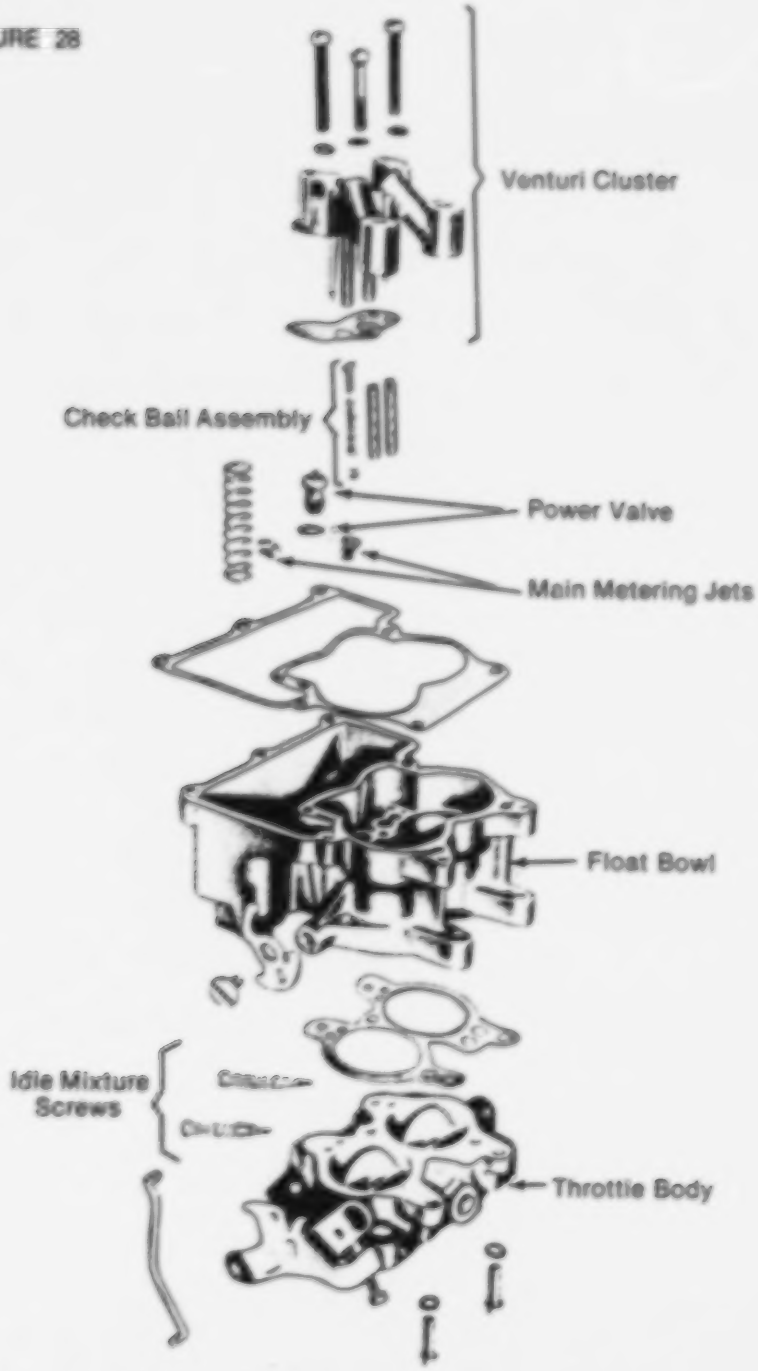
C. Disassemble throttle body and choke

(NOTE: Refer to Figure 28 on following page.)

1. Remove fast idle cam attaching screws
2. Remove choke cover screws and cover
3. Remove cover gasket and baffle plate from choke housing
4. Remove choke piston attaching screw; remove piston link and lever assembly
5. Remove choke housing attaching screws and choke housing
6. Remove choke housing gasket, choke lever, and linkage from choke housing

JOB SHEET #7

FIGURE 28



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JOB SHEET #7

7. Remove idle mixture needle screws as required for cleaning or replacement

(NOTE: No attempt should be made to remove the throttle valves or shafts.)

D. Clean parts

(CAUTION: Do not pass drills through jets or passages.)

1. Clean carburetor castings and metal parts thoroughly in cleaning solvent

(NOTE: The choke coil, housing, and pump plunger should not be immersed in solvent.)

2. Clean and dry all casting passages with compressed air

(CAUTION: Always wear safety glasses when using compressed air.)

E. Inspect parts

1. Check float for dents or excessive wear at hinge pin holes
2. Shake float to check for leaks
3. Examine float needle and seat for ridges; replace with a new matched set as required
4. Inspect idle mixture adjusting needles for burrs or ridges; replace if necessary
5. Inspect all linkages and linkage arms for excessive wear; replace as required
6. Inspect pump plunger for cracks or creases; replace if damaged
7. Inspect throttle body to make sure idle passages and vacuum channels are open

F. Reassemble throttle body

1. Install slow idle speed screw
2. Install fast idle lever on end of throttle shaft with attaching screw; install fast idle speed screw and spring in lever

JOB SHEET #7

3. Install idle mixture needles and spring in throttle body

   (NOTE: Tighten finger tight, then back out one and one-half turns as a preliminary idle adjustment.)

4. Install choke lever and shaft in choke shaft

5. Install choke housing gasket and choke housing

6. Install choke piston lever and link assembly

7. Position fast idle cam on throttle body; install attaching screw

8. Place a new gasket on bottom of float bowl, align holes, and install throttle body screws; tighten evenly and securely

G. Reassemble float bowl

1. Install pump discharge ball, spring, and guide

2. Install venturi cluster, gasket, and attaching screws

   (NOTE: Screw with gasket must be inserted in center hole.)

3. Install main metering jets and power valve

4. Install pump inlet ball and return spring in pump well

5. Install screen and baffle if required

H. Reassemble air horn

1. Install choke unloader

2. Install choke shaft and choke valve

   (NOTE: Center the choke valve in the choke shaft before tightening screws.)

3. Install pump plunger

4. Position float needle seat gasket; install seat in air horn

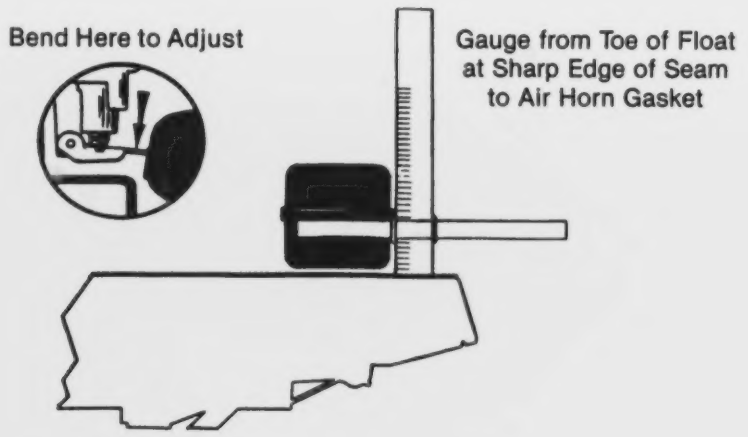
5. Install power piston and lightly shake casting; make sure that piston moves freely

6. Install air horn gasket, float, needle assembly, and float hinge pin

JOB SHEET #7

7. Adjust float level according to manufacturer's specifications (Figure 29)

FIGURE 29



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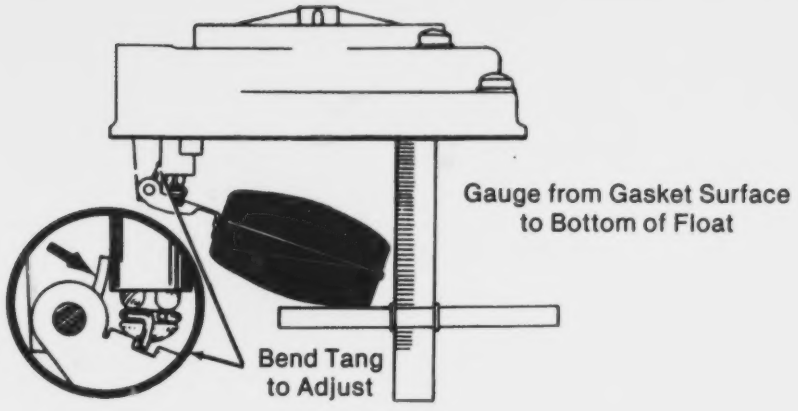
8. Adjust float drop according to manufacturer's specifications (Figure 30)

FIGURE 30



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JOB SHEET #7

I. Install air horn on float bowl while guiding accelerator pump into place; install and tighten air horn screws evenly and securely

J. Position upper end of pump rod on pump lever; retain with spring clip

K. Position idle vent valve and shield on air horn; retain with attaching screw

L. Install choke unloader screw

M. Make additional adjustments according to manufacturer's recommendations

N. Clean and put away tools and equipment

FUEL SYSTEMS
UNIT III

TEST

NAME _____ _____ SCORE _____

1. Match terms associated with fuel systems to their correct definitions. Write the correct numbers in the blanks. Definitions are continued on the next page.

_____a.	Projection	1. Torque
_____b.	Breaking up of a liquid into tiny particles or globules to aid evaporation	2. Rheostat
_____c.	Act or operation of burning	3. Tang or lug
_____d.	Flexible partition between two chambers	4. Solenoid
_____e.	Restriction in carburetor that makes the air speed up, causing a vacuum	5. Atomization
_____f.	Process of mixing fuel and air to correct proportions for good combustion	6. Diaphragm
_____g.	Device that distributes fuel into combustion chamber	7. Fuel injection system
_____h.	Unit containing an element of varying degrees of fineness to trap foreign particles	8. Backup wrench
_____i.	Pump and injection nozzle combined into one unit	9. Unit injector
_____j.	System in which pump delivers fuel to an injection nozzle that atomizes the fuel and distributes it under pressure to the combustion chamber	10. Atomize
_____k.	Turning or twisting force	11. Combustion
_____l.	Device made of wire or carbon that presents a resistance to current flow	12. Venturi
_____m.	Resistor for regulating current by means of variable resistance	13. Cross threading
_____n.	Second wrench used to hold a part, such as a gas line fitting, while opposite end of fitting is loosened or tightened	14. Resistor
		15. Injection nozzle
		16. Filter
		17. Metering

TEST

_____o. Electromagnetic switch

_____p. Screwing any two threads together crookedly

_____q. To reduce to a fine spray

2. State the purpose of the fuel system.

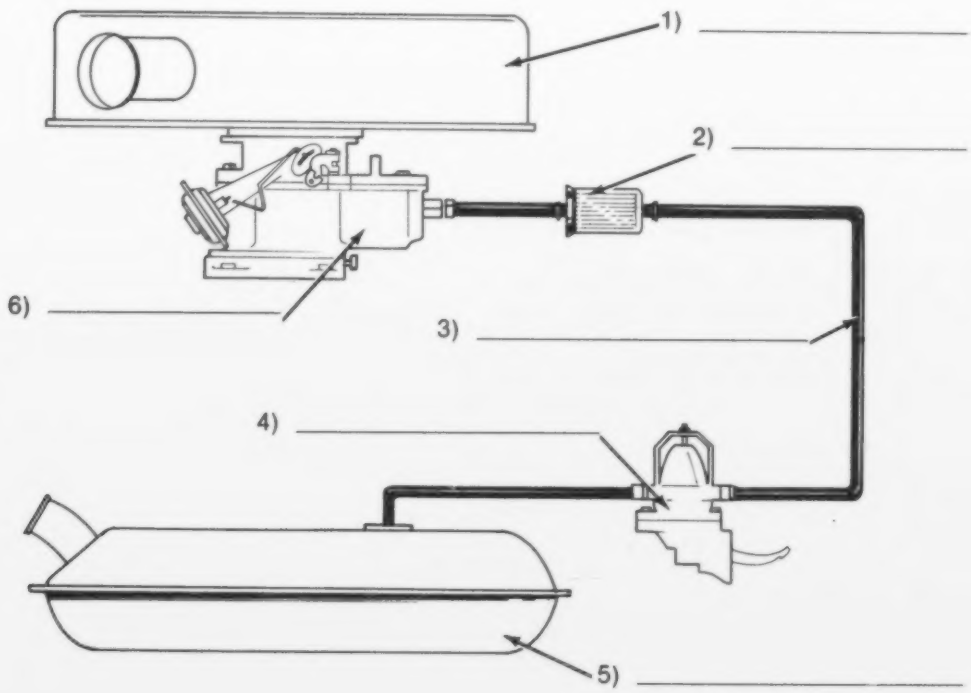
_____

_____

_____

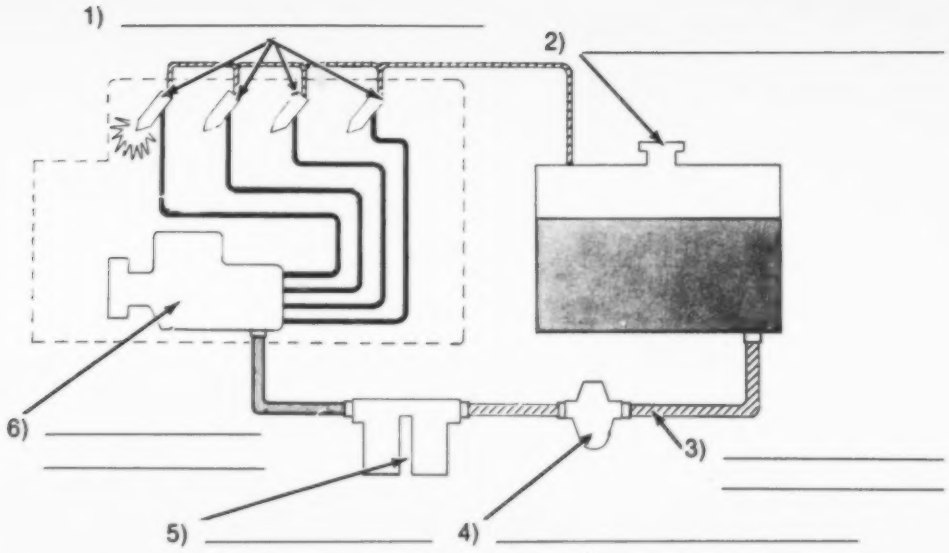
3. Label components of gasoline and diesel fuel systems.

a. Gasoline



TEST

b. Diesel



4. Match fuel system components to their correct purposes. Write the correct numbers in the blanks.

_____a.	Stores fuel for engine use	1. Fuel pump
_____b.	Prevents dirt and foreign matter from entering system	2. Carburetor
_____c.	Pumps fuel from fuel tank through carburetor	3. Transfer pump
_____d.	Atomizes and sprays fuel into combustion chamber of diesel engine	4. Injection nozzle
_____e.	Mixes gasoline and air in proper proportion for a combustible mixture	5. Air cleaner
_____f.	Supplies fuel through filters to injection pump at low pressure	6. Fuel tank
_____g.	Filters grit and dust from air entering carburetor in gasoline engine	7. Injection pump
_____h.	Times, measures, and delivers fuel under pressure to injection nozzles in diesel engine	8. Fuel lines
_____i.	Carry fuel from fuel tank through system	9. Fuel filter

TEST

5. Describe fuel pump operation during inlet and outlet strokes.

   a. Inlet stroke — _____

   _____

   _____

   _____

   b. Outlet stroke — _____

   _____

   _____

   _____

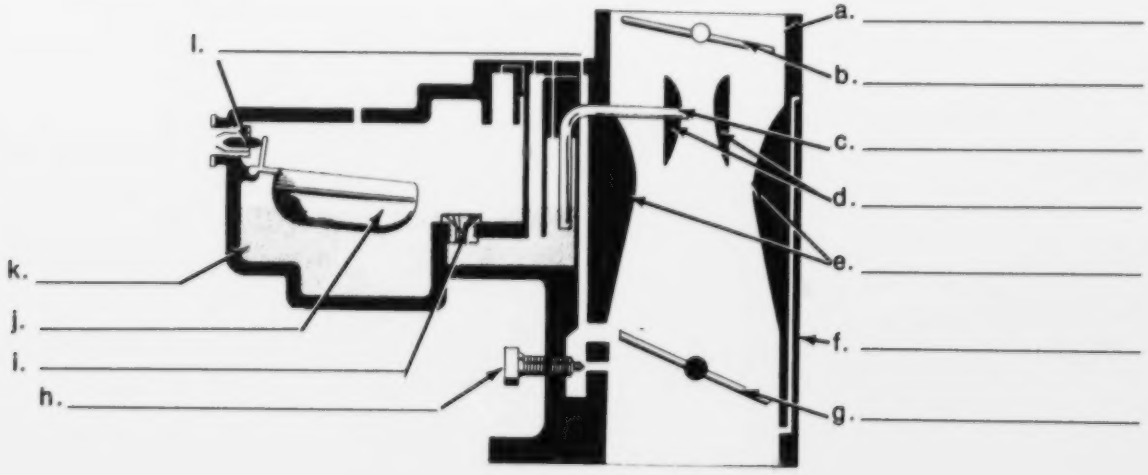
6. List three major functions of the fuel injection system.

   a. _____

   b. _____

   c. _____

7. Label basic parts of the carburetor illustrated below.



TEST

8. Match carburetor systems to their correct uses. Write the correct numbers in the blanks.

_____a.	Maintains a given depth of fuel in float bowl	1. Main metering system
_____b.	Provides fuel delivery during operation with throttle partly to fully open	2. Choke system
_____c.	Provides fuel delivery when throttle is closed or nearly closed	3. Float system
_____d.	Provides extra fuel for maximum engine power to supplement main metering system	4. Accelerator pump system
_____e.	Provides a rich mixture for cold engine starting and operation	5. Power system
_____f.	Temporarily provides extra fuel necessary to overcome leanness caused by rapid throttle opening	6. Idle system

9. Name the three major types of fuel injection systems.

a. _____

b. _____

c. _____

10. Describe three variations of fuel injection systems.

a. _____

_____

b. _____

_____

c. _____

_____

TEST

11. List three methods of injecting fuel using the pump and injection nozzle.

a. _____

_____

b. _____

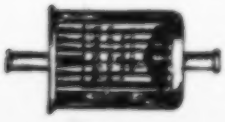
_____

c. _____

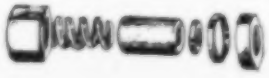
_____

12. Identify types of fuel filters. Write the correct names in the blanks.

In-line **Bowl** **Disposable element** **Carburetor inlet**



a. _____



b. _____

c. _____

d. _____

13. Distinguish between operation of series and parallel dual filters. Write an "X" in the blank pertaining to parallel.

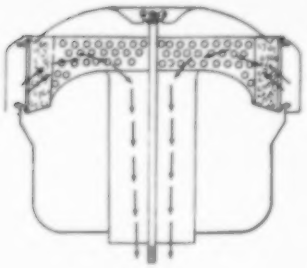
_____a. Part of fuel flows through each filter

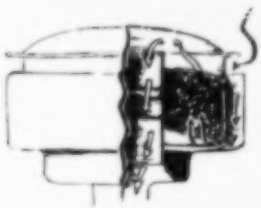
_____b. All fuel flows through one filter before flowing through the other

TEST

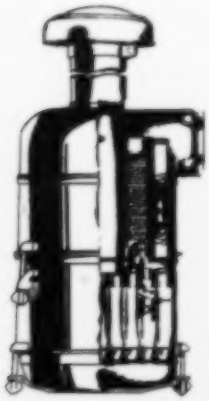
14. Identify types of air cleaners. Write the correct names in the blanks. Some answers may be used more than once.

Oil bath **Viscous impingement** **Dry element**





a. _____ b. _____



c. _____ d. _____

TEST

15. Match types of fuel lines to their correct purposes. Write the correct numbers in the blanks.

_____a.	Transfers fuel between injection pump and injector	1. Light weight (no pressure)
_____b.	Transfers leak-off fuel from injectors to tank or pump	2. Heavy weight (high pressure)
_____c.	Transfers fuel between tank and filter, and between filter and injection pump	3. Medium weight (low pressure)

(NOTE: Test question 16 lists the job sheets. They are an important part of this test. If they have not been completed, check with your instructor.)

16. Demonstrate the ability to

a. Volume and pressure test a fuel pump.

b. Remove and replace a fuel pump.

c. Inspect air cleaner service indicator and service air cleaner.

d. Service oil-bath-type air cleaner.

e. Remove and replace an in-line fuel filter.

f. Remove and replace a carburetor.

g. Disassemble, adjust, and reassemble a carburetor.

FUEL SYSTEMS
UNIT III

ANSWERS TO TEST

1.	a.	3	g.	15	m.	2
	b.	5	h.	16	n.	8
	c.	11	i.	9	o.	4
	d.	6	j.	7	p.	13
	e.	12	k.	1	q.	10
	f.	17	l.	14		

2. To supply a combustible mixture of air and fuel to operate engine to meet all operating requirements

3.

a. Gasoline	b. Diesel
1) Air cleaner	1) Injection nozzles
2) Fuel filter	2) Fuel tank
3) Fuel line	3) Fuel line
4) Fuel pump	4) Fuel transfer pump
5) Fuel tank	5) Fuel filters
6) Carburetor	6) Injection pump (distributor type)

4.	a.	6	f.	3	
	b.	9	g.	5	
	c.	1	h.	7	
	d.	4	i.	8	
	e.	2			

ANSWERS TO TEST

5. Description should include the following

   a. Inlet stroke

      1) Diaphragm flexes downward, forming a vacuum

      2) Inlet check valve opens

      3) Fuel is drawn into pump

   b. Outlet stroke

      1) Diaphragm is pushed upward by return spring

      2) Inlet valve is forced shut

      3) Outlet valve is forced open

      4) Fuel is forced out of pump

6. Answer should include any three of the following

   a. Supplies correct quantity of fuel

   b. Times fuel delivery

   c. Controls delivery rate

   d. Atomizes fuel

   e. Distributes fuel evenly throughout combustion chamber

7.

a.	Air horn	g.	Throttle valve
b.	Choke valve	h.	Mixture screw
c.	Nozzle	i.	Jet
d.	Venturi cluster	j.	Float
e.	Venturi	k.	Float bowl
f.	Throttle body	l.	Needle valve assembly

ANSWERS TO TEST

8. a. 3 d. 5
   b. 1 e. 2
   c. 6 f. 4

9. a. Common-rail system
   b. Accumulator system
   c. Jerk-pump system

10. Description should include any three of the following
    a. Mechanical — Metering of fuel is controlled by mechanical devices such as cams, levers, and gears
    b. Electronic — Metering of fuel is controlled by electronic devices such as solenoids, resistors, and rheostats
    c. Combustion chamber injection — Fuel under pressure is injected directly into combustion chamber
    d. Port injection — Fuel under high pressure is injected into intake air flow
    e. Constant flow injection — Fuel is metered into air flow at all times; volume of fuel is varied as engine speed and load change
    f. Timed injection — Fuel is metered into air flow at specific times in engine cycle as needed; length of time injector is open is varied to adjust volume of fuel as engine speed and load change

11. Answer should include any three of the following
    a. Individual pump and injection nozzle for each cylinder
    b. Combined pump and injection nozzle for each cylinder (unit injector type)
    c. Pumps in common housing with injection nozzle for each cylinder (in-line type)
    d. One pump serving injection nozzles for several cylinders (distributor type)

12. a. In-line
    b. Carburetor inlet
    c. Bowl
    d. Disposable element

ANSWERS TO TEST

13. a

14. a. Viscous impingement
    b. Oil bath
    c. Dry element
    d. Oil bath

15. a. 2
    b. 1
    c. 3

16. Performance skills evaluated to the satisfaction of the instructor

COOLING SYSTEMS
UNIT IV

UNIT OBJECTIVE

After completing this unit, the student should be able to pressure test a cooling system and remove and reinstall parts of the cooling system. The student will show this knowledge by completing job sheets and unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match to their correct definitions terms associated with cooling systems.
2. Describe the purpose of the cooling system.
3. State jobs performed by the cooling system.
4. Identify components of gasoline and diesel cooling systems.
5. Distinguish between characteristics of liquid and air cooling systems.
6. Select from a list types of thermostats.
7. Distinguish between thermostat operation in a cold engine and in an engine at operating temperature.
8. Label the two types of radiators.
9. Distinguish between characteristics of downflow and crossflow radiators.
10. Describe pressure cap operation at various temperatures.
11. Name types of fans used in cooling systems.
12. Describe operation of the variable-speed fan drive.
13. State reasons for using permanent-type antifreeze in the cooling system.
14. Identify basic parts of a water pump and fan.
15. Demonstrate the ability to
    a. Remove, check, and reinstall a thermostat.
    b. Pressure test the cooling system.

OBJECTIVE SHEET

c. Reverse flush a radiator.

d. Remove and reinstall a water pump and fan belt.

e. Remove and reinstall a radiator.

f. Test antifreeze solution.

g. Test for exhaust-gas leakage and air in the cooling system.

COOLING SYSTEMS
UNIT IV

SUGGESTED ACTIVITIES

I. Suggested activities

A. Order films and other materials planned to supplement unit.

(NOTE: Manufacturers are excellent sources for visual aids to demonstrate cooling-system operation and for slide and film presentations on gasoline and diesel engines. Write directly to the appropriate company or manufacturer.)

B. Gather equipment and materials for job sheet demonstrations.

C. Obtain transparencies.

(NOTE: Transparencies are available from AGC and CIMC.)

D. Provide students with objective sheet.

E. Discuss unit and specific objectives.

F. Provide students with information and job sheets.

G. Discuss information sheet.

H. Demonstrate and discuss procedures outlined in job sheets.

I. Give test.

J. Complete appropriate section of competency profiles.

(NOTE: Competency profiles are available from AGC and CIMC.)

II. Instructional materials

A. Objective sheet

B. Suggested activities

C. Information sheet

D. Transparency masters

1. TM #1 — Thermostat Operation

2. TM #2 — Types of Radiators

SUGGESTED ACTIVITIES

3. TM #3 — Downflow and Crossflow Radiators
4. TM #4 — Pressure Cap Operation
5. TM #5 — Fan Types
6. TM #6 — Variable-Speed Fan Drive
7. TM #7 — Basic Parts of Water Pump and Fan

E. Job sheets

1. Job Sheet #1 — Remove, Check, and Reinstall a Thermostat
2. Job Sheet #2 — Pressure Test the Cooling System
3. Job Sheet #3 — Reverse Flush a Radiator
4. Job Sheet #4 — Remove and Reinstall a Water Pump and Fan Belt
5. Job Sheet #5 — Remove and Reinstall a Radiator
6. Job Sheet #6 — Test Antifreeze Solution
7. Job Sheet #7 — Test for Exhaust-Gas Leakage and Air in the Cooling System

F. Test

G. Answers to test

III. Unit references

A. Armstrong, Ivan J. *Auto Mechanics,* Vol. I. Stillwater, Oklahoma: State Department of Vocational and Technical Education/Curriculum and Instructional Materials Center, 1976.

B. Foutes, William A. *Diesel Engine Mechanics.* Stillwater, Oklahoma: Mid-America Vocational Curriculum Consortium, Inc., 1977.

C. Foutes, William A. *Diesel Mechanics: Fundamentals.* Stillwater, Oklahoma: Mid-America Vocational Curriculum Consortium, Inc., 1977.

COOLING SYSTEMS
UNIT IV

INFORMATION SHEET

I. Terms and definitions

A. Aeration — Process of mixing air and water

B. Bimetallic — Pertaining to two strips of dissimilar metal welded together, one of which expands more when heated than the other

C. Coolant — Liquid that circulates through cooling system to transfer engine heat

D. Fan — Device mounted on water-pump hub assembly; used to move large amounts of air so that heat may be transferred from coolant to air

E. Pressure cap — Cap that increases pressure within cooling system several pounds per square inch; allows coolant to circulate at higher temperatures without evaporation or surge loss

F. Radiator — Device for holding a considerable volume of coolant in close contact with a large amount of air so that heat may be transferred from coolant to air

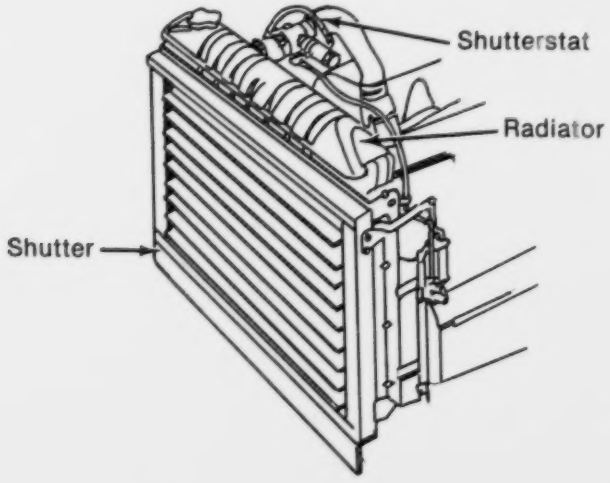
G. Radiator hose — Hose used to connect radiator to engine

INFORMATION SHEET

H. Radiator shutter — Device over radiator; used to maintain temperature variations of coolant (Figure 1)

EXAMPLE: Typical air-operated shuttle assembly

FIGURE 1



I. Shroud — Funnel-like structure attached to radiator, extending around and behind fan; used to make fan more effective in pulling air through radiator

J. Thermostat — Heat-controlled valve in cooling system; used to regulate flow of coolant between cylinder block and radiator

K. V-belt — Belt turned by a pulley on the front of crankshaft; used to drive water pump, fan, and other engine accessories

L. Water jacket — Passage through block and cylinder head that allows coolant to circulate around cylinders, valves, and combustion chambers

M. Water pump — Centrifugal pump mounted at front of cylinder block; circulates coolant throughout cooling system

II. Purpose of the cooling system — To keep the engine at its most efficient operating temperature during all engine speeds and operating conditions

III. Jobs performed by the cooling system

A. Removing surplus or unwanted heat

B. Maintaining an efficient temperature under all operating conditions

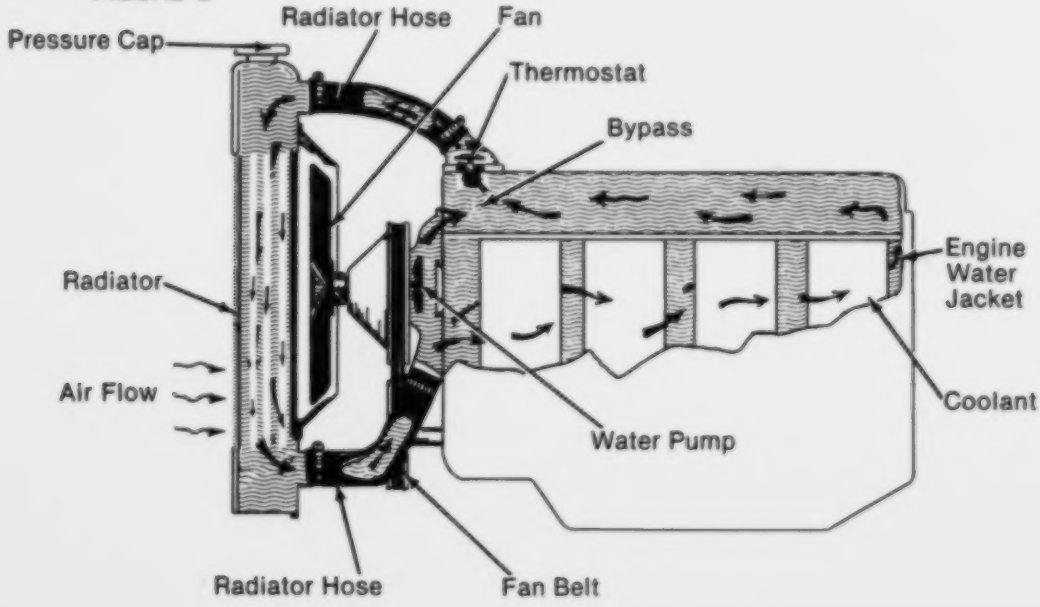
C. Bringing engine to operating temperature as soon after starting as possible

INFORMATION SHEET

IV. Components of gasoline and diesel cooling systems (Figures 2 and 3)

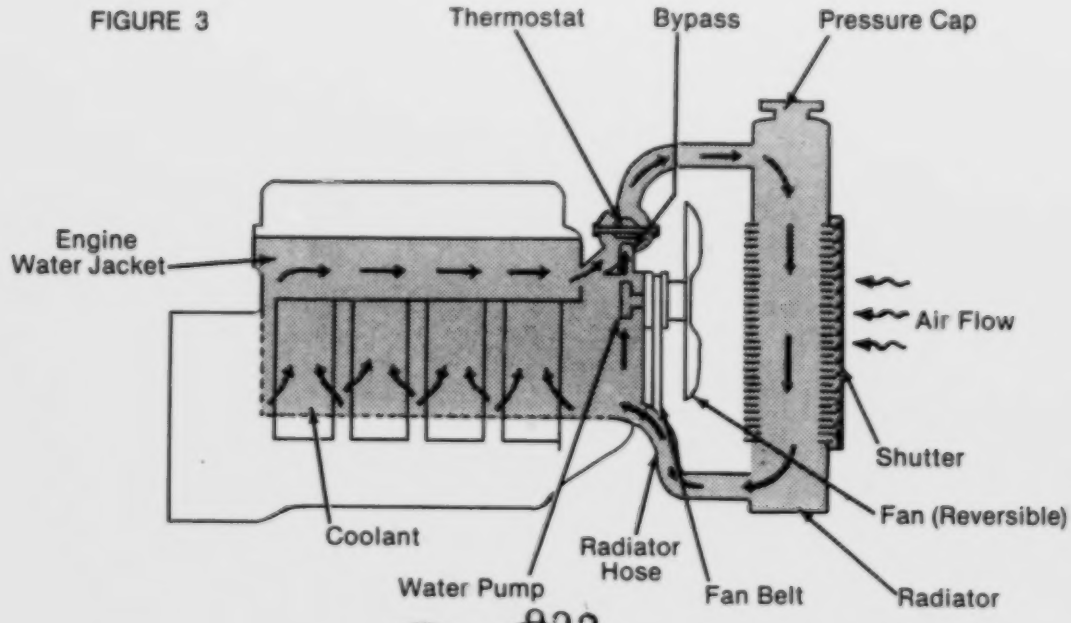
A. Gasoline

FIGURE 2



B. Diesel

FIGURE 3



INFORMATION SHEET

V. Characteristics of liquid and air cooling systems

A. Liquid — Uses circulating coolant

B. Air — Uses a fan, cooling fins, and shrouding

VI. Types of thermostats

A. Bellows

B. Bimetallic

C. Pellet

VII. Thermostat operation (Transparency #1)

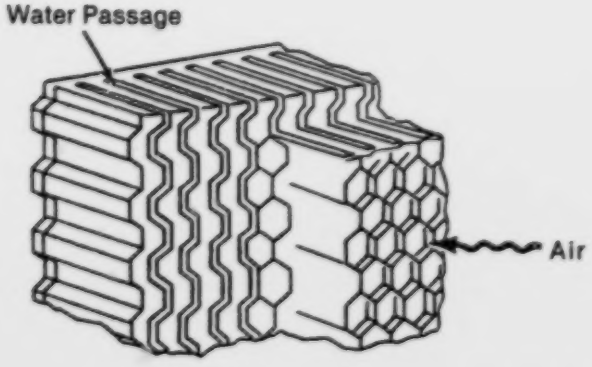
A. Cold engine — Thermostat shuts off flow of coolant from engine to radiator to allow quicker engine warm-up

B. Engine at operating temperature — Thermostat is open and allows coolant to circulate through system

VIII. Types of radiators (Figures 4 and 5; Transparency #2)

A. Cellular-type core

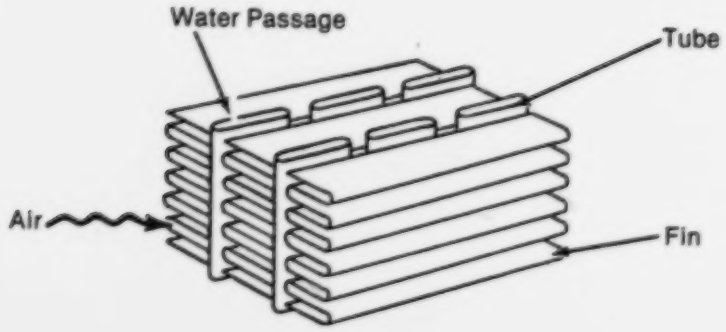
FIGURE 4



INFORMATION SHEET

B. Tube-and-fin-type core

FIGURE 5



IX. Characteristics of downflow and crossflow radiators (Transparency #3)

A. Downflow radiator

1. Has tanks on top and bottom

2. Coolant flows from top to bottom

B. Crossflow radiator

1. Has tanks on sides

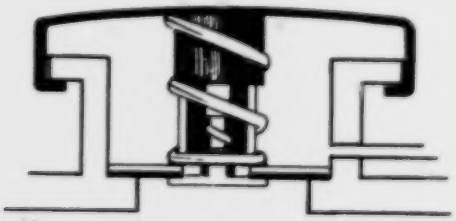
2. Coolant flows from side to side across radiator

X. Pressure cap operation at various temperatures (Transparency #4)

A. Cooling system at normal temperature — Pressure cap fits over radiator filler tube and seals tightly around the edges to prevent evaporation or surge loss (Figure 6)

EXAMPLE: Valves closed

FIGURE 6

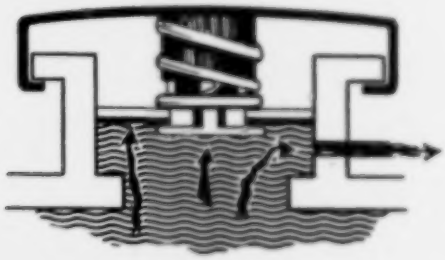


INFORMATION SHEET

B. Cooling system very hot with built-up excess pressure — Blowoff valve has calibrated spring that opens to release excess pressure in cooling system (Figure 7)

EXAMPLE: Pressure valve open

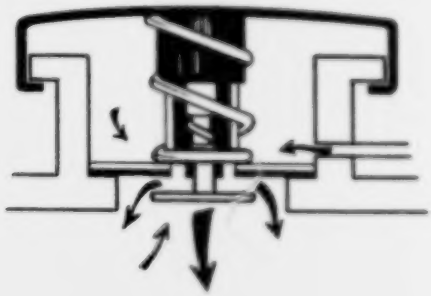
FIGURE 7



C. Cooling system during cooling-off period — Vacuum valve opens to allow air to enter cooling system to prevent collapse of radiator and hoses (Figure 8)

EXAMPLE: Vacuum valve open

FIGURE 8



XI. Types of fans used in cooling systems (Transparency #5)

A. Blower

B. Suction

C. Reversible

INFORMATION SHEET

XII. Operation of the variable-speed fan drive (Transparency #6)

A. When engine temperatures are high, the fan speed is increased to aid cooling

B. When engine temperatures are low, the fan speed is decreased to conserve engine power

XIII. Reasons for using permanent-type antifreeze in the cooling system

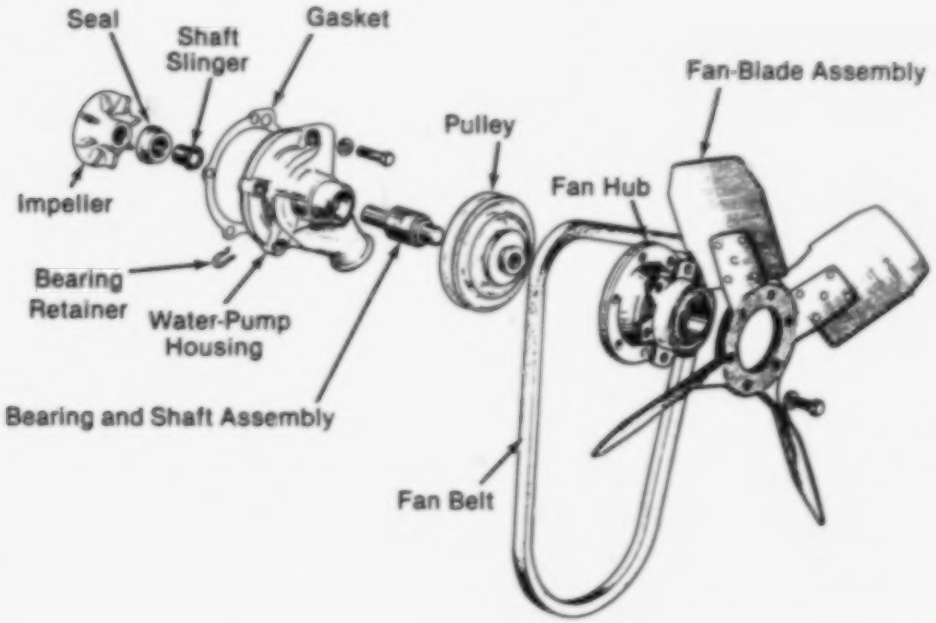
A. Prevents coolant from freezing

B. Has a higher boiling point than water

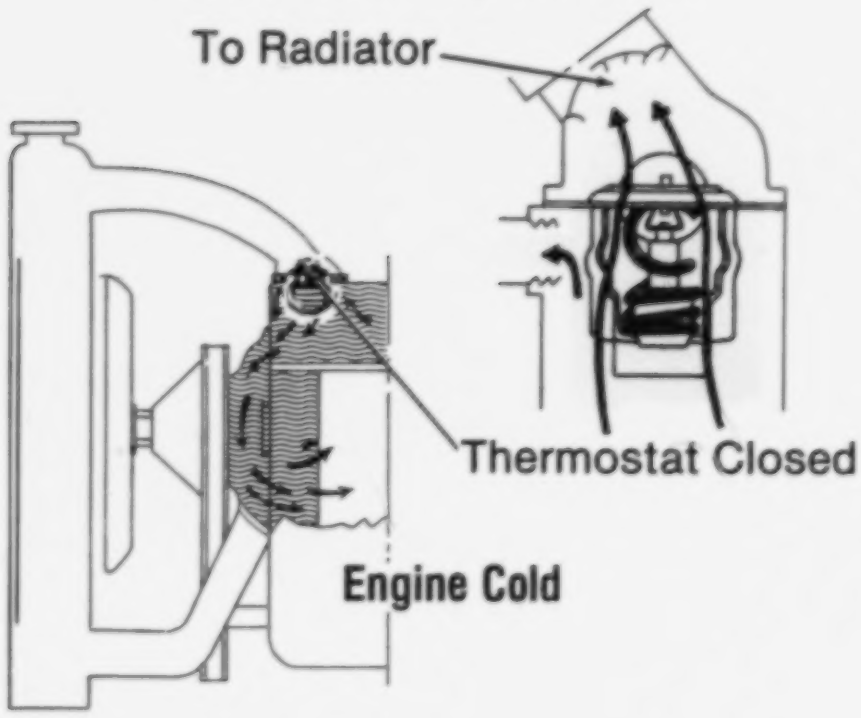
C. Reduces the corrosive action of water

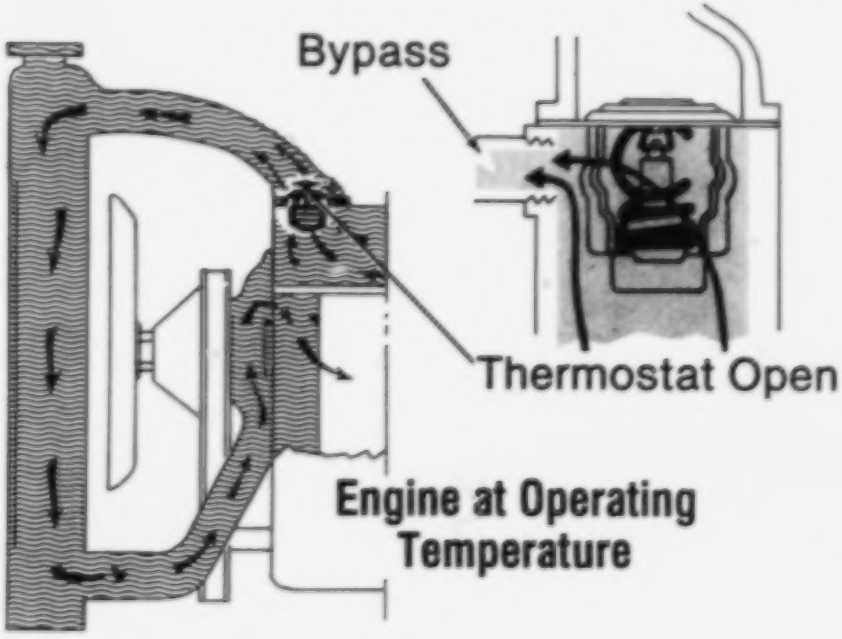
XIV. Basic parts of a water pump and fan (Figure 9; Transparency #7)

FIGURE 9

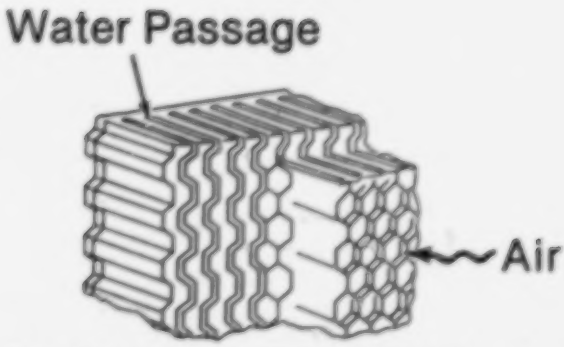


Thermostat Operation

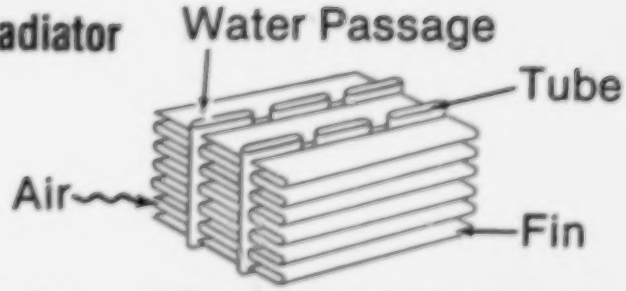




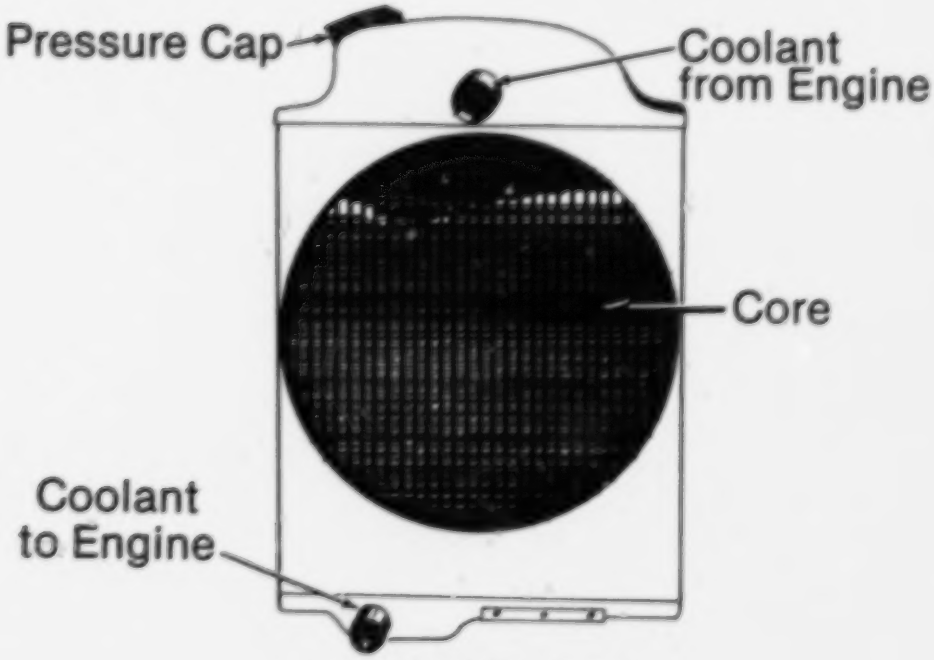
Types of Radiators



Cellular-Type Core Radiator



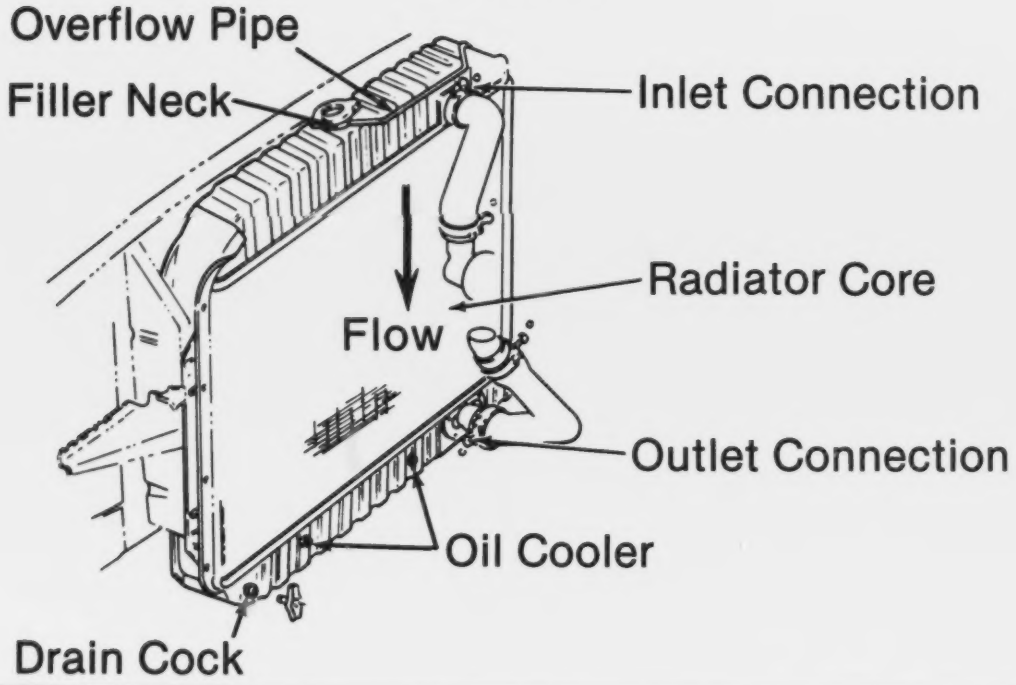
Tube-and-Fin-Type Core Radiator



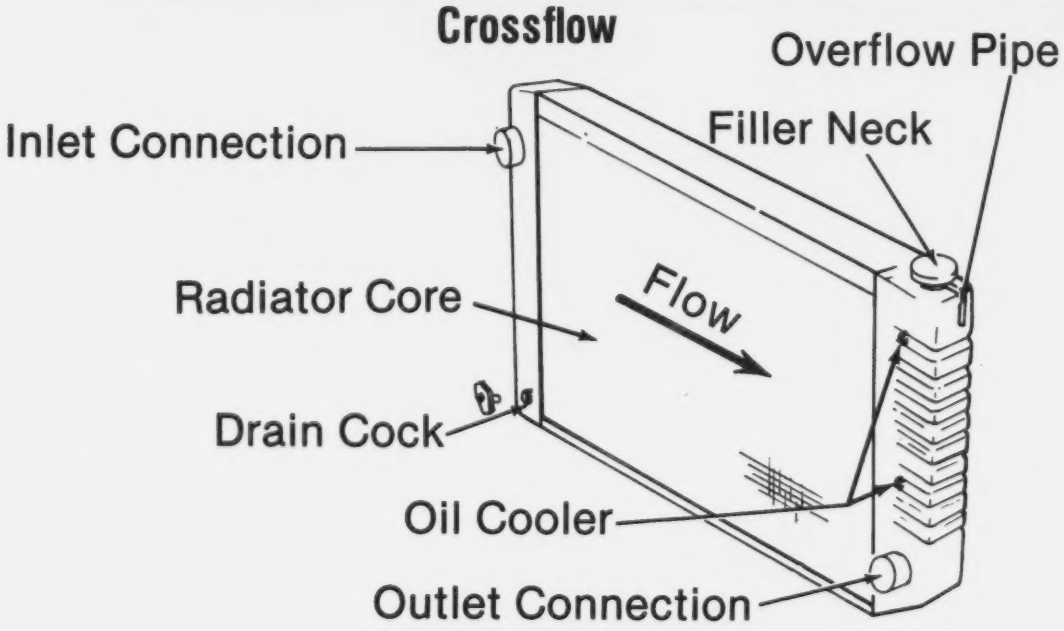
Typical Radiator

Downflow and Crossflow Radiators

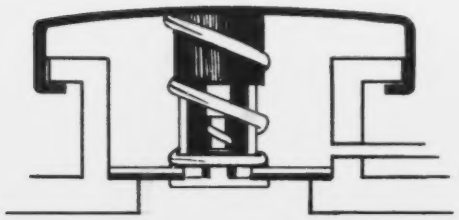
Downflow



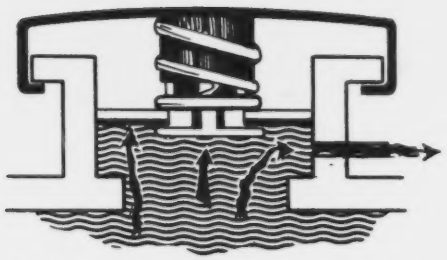
Crossflow



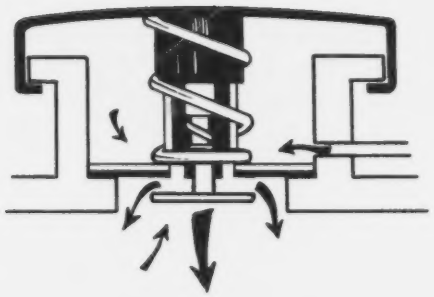
Pressure Cap Operation



Valves Closed



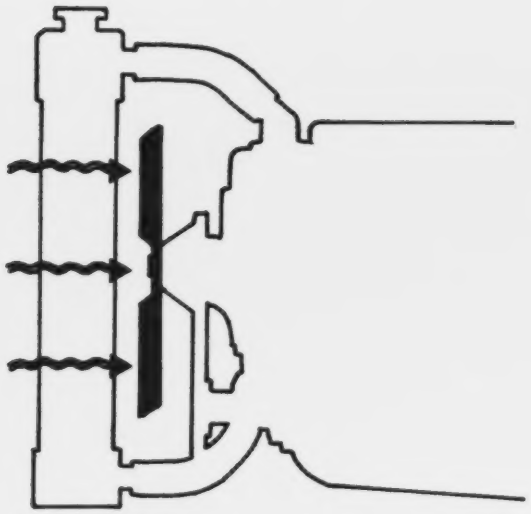
Pressure Valve Open



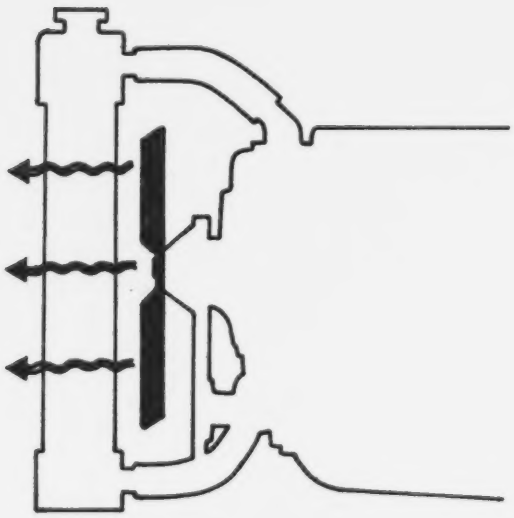
Vacuum Valve Open

1000

Fan Types



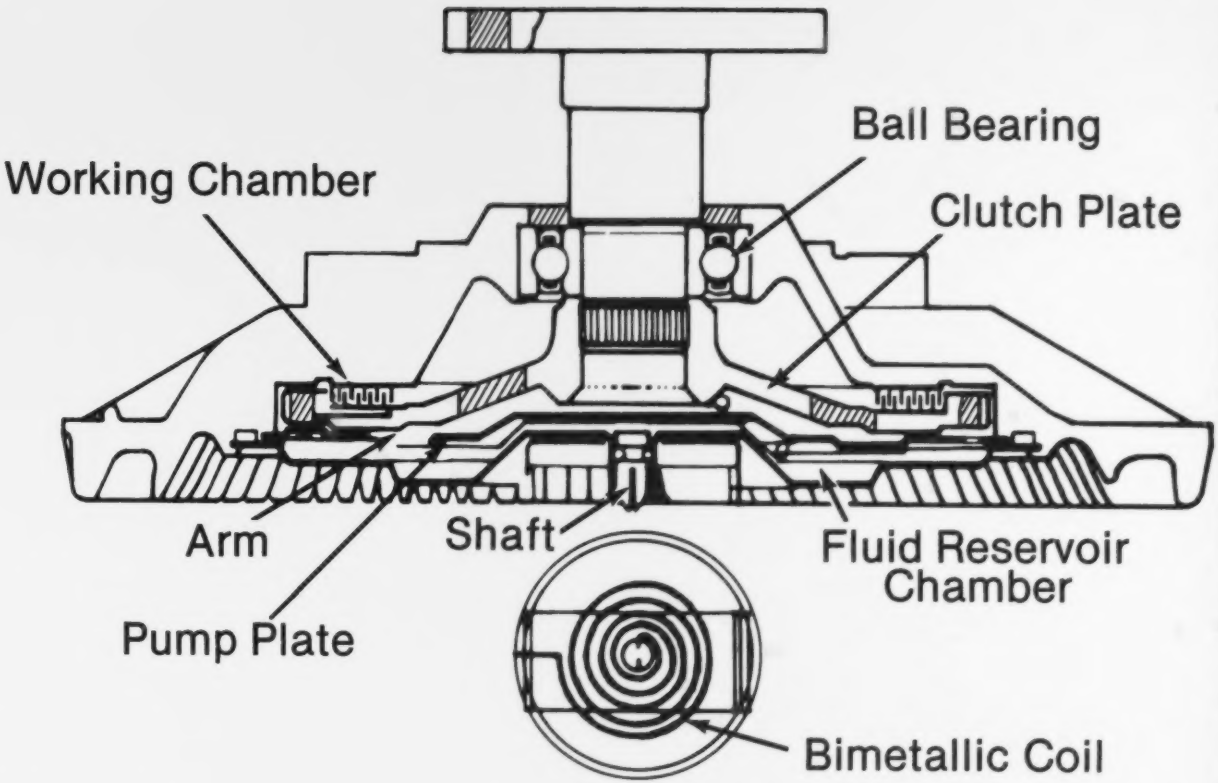
Suction Fan



Blower Fan

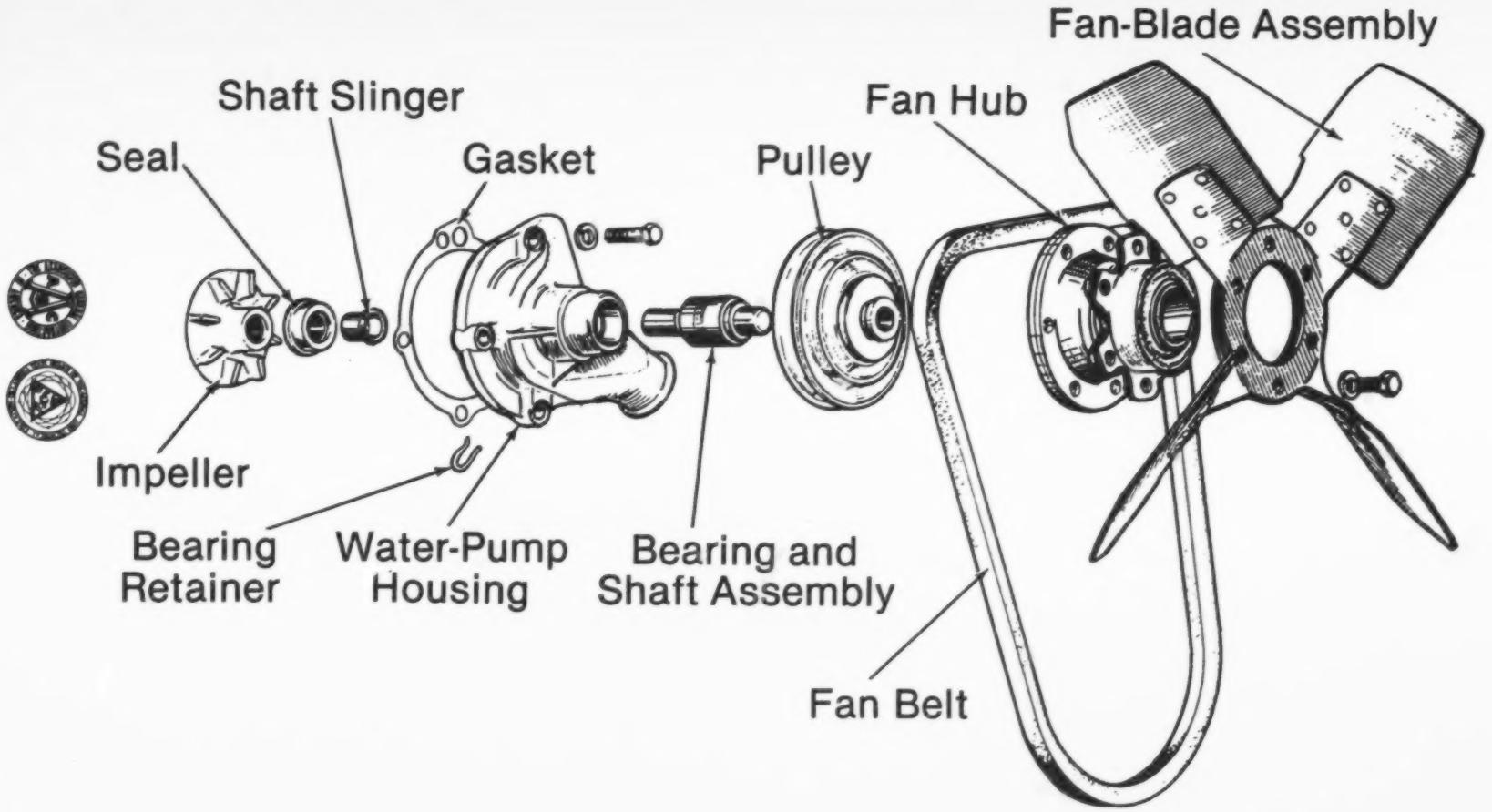
1001

Variable-Speed Fan Drive



TM #8

Basic Parts of Water Pump and Fan



TM #7

1003

1004

HEM - 251-C

COOLING SYSTEMS
UNIT IV

JOB SHEET #1 — REMOVE, CHECK, AND REINSTALL A THERMOSTAT

I. Equipment and materials

- A. Vehicle
- B. Basic hand-tool set
- C. Drain pan
- D. Hose-clamp pliers
- E. Container of water
- F. High-temperature thermometer
- G. New gasket
- H. Gasket scraper
- I. Gasket sealer
- J. Torque wrench
- K. Radiator fill can
- L. Shop towels
- M. Appropriate service manual

II. Procedure

- A. Drain coolant to a level below thermostat
- B. Remove radiator hose connected to thermostat outlet if required
- C. Remove thermostat-housing retaining bolts
- D. Remove thermostat housing
- E. Remove thermostat
- F. Determine condition of thermostat

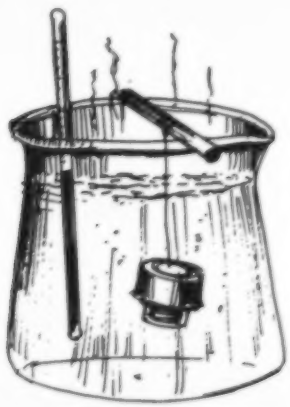
(NOTE: Discard thermostat if it is excessively rusted, bent, or stuck in an open position.)

JOB SHEET #1

G. Check thermostat opening

1. Suspend thermostat in a container of water that contains a high-temperature thermometer (Figure 10)

FIGURE 10



2. Heat the container; observe the temperature at which the thermostat begins to open, and the temperature at full-open position

a. Discard thermostat if it fails to respond at specified temperatures

(NOTE: The thermostat should start to open at 180°F to 185°F [82°C to 85°C] and should be fully open at 200°F to 202°F [93°C to 95°C].)

b. Reinstall thermostat if it responds correctly

H. Clean thermostat seat and thermostat housing

(NOTE: Remove all traces of gasket and rust.)

JOB SHEET #1

I. Place thermostat into thermostat opening (Figure 11)

(NOTE: Make sure that the bellows or spring on the thermostat is placed toward the cylinder block.)

FIGURE 11

J. Install new gasket with gasket sealer as required

K. Install thermostat housing; start retaining bolts

L. Tighten bolts uniformly and to specified torque

M. Install hose and tighten clamps securely

N. Fill cooling system with recommended coolant

O. Start engine

P. Check for leaks

Q. Recheck the coolant level after the engine is warm

R. Clean work area; put away all tools and equipment

COOLING SYSTEMS
UNIT IV

JOB SHEET #2 — PRESSURE TEST THE COOLING SYSTEM

I. Equipment and materials

A. Vehicle

B. Radiator pressure tester

II. Procedure

A. Remove radiator cap

(CAUTION: Never remove the radiator cap quickly when the engine is hot. If cap must be removed when the engine is hot, loosen cap to first stop and leave in this position until all pressure is released. Cap can then be removed safely.)

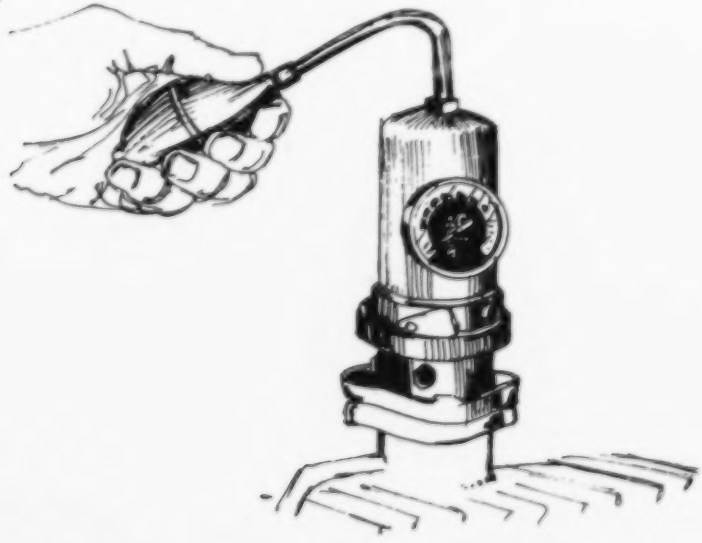
B. Wipe clean the seat of the radiator filler cap

C. Attach radiator pressure tester

D. Apply pressure (Figure 12)

(NOTE: Pressure applied should not exceed recommended cooling-system pressure by more than 1 pound per square inch [psi].)

FIGURE 12



JOB SHEET #2

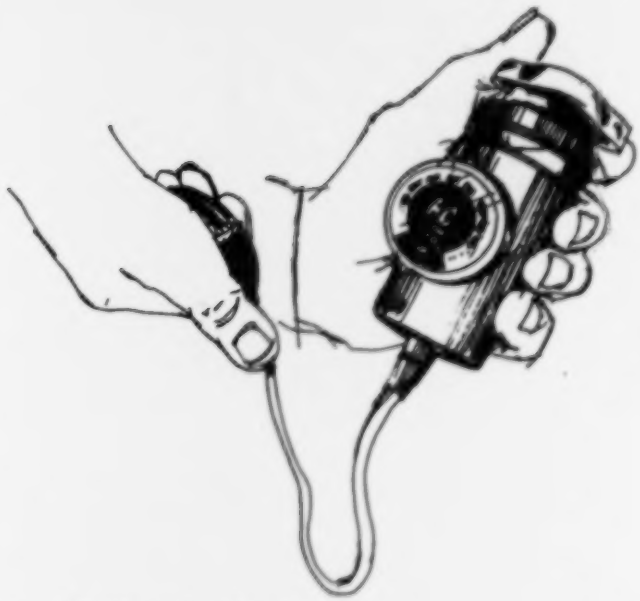
1. If pressure holds steady, perform the following steps

   (NOTE: The cooling system is not leaking if pressure remains steady.)

   a. Test pressure cap (Figure 13)

      (NOTE: Use the radiator pressure tester with adapter. If the cap does not hold the rated pressure, replace it.)

FIGURE 13



   b. Check coolant level

   c. Reinstall cap

2. If pressure drops, perform the following steps

   a. Check for external leaks in hose connections, expansion plugs, water pump, and radiator

   b. Check for internal leaks

      1) Remove tester

      2) Start and run engine until operating temperature is reached

      3) Reattach pressure tester

      4) Apply cooling-system pressure

JOB SHEET #2

5) Increase engine speed to half-throttle

a) If pressure-gauge needle fluctuates, there is a combustion leak

(NOTE: If combustion leaks are evident, the engine will have to be disassembled for repairs.)

b) If pressure-gauge needle does not fluctuate, sharply accelerate engine several times and check for a discharge of water from the tail pipe

(NOTE: An abnormal amount of water discharged at the tail pipe could indicate a cracked block or head, or a defective head gasket.)

6) Test pressure cap

(NOTE: Refer to Figure 12. Use radiator pressure tester with adapter. If the cap does not hold the rated pressure, replace it.)

7) Check coolant

8) Reinstall cap

E. Clean work area; clean and put away radiator pressure tester

COOLING SYSTEMS
UNIT IV

JOB SHEET #3 — REVERSE FLUSH A RADIATOR

I. Equipment and materials

A. Vehicle

B. Drain pan

C. Flushing gun

D. Basic hand-tool set

E. Water source

F. Compressed-air source

G. Safety glasses

H. Radiator fill can

II. Procedure

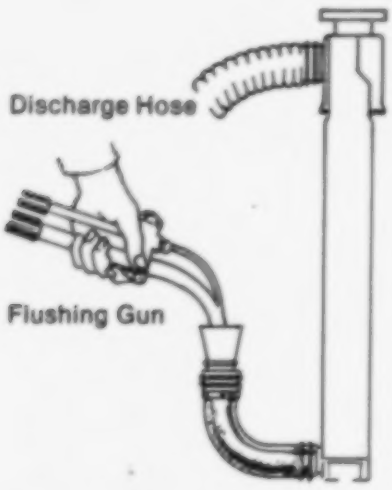
A. Drain radiator

B. Disconnect both hoses

C. Connect flushing-gun hose to water source and air source of 100 psi

D. Connect flushing-gun nozzle to lower radiator hose (Figure 14)

FIGURE 14



JOB SHEET #3

E. Turn on water

F. Fill radiator

G. Inject air in short bursts to clear the tubes

H. Allow radiator to fill between bursts

I. Continue until water flows freely

J. Clean work area; clean and put away all tools and equipment

COOLING SYSTEMS
UNIT IV

JOB SHEET #4 — REMOVE AND REINSTALL
A WATER PUMP AND FAN BELT

I. Equipment and materials

A. Vehicle

B. Basic hand-tool set

C. Drain pan

D. Hose-clamp pliers

E. Pump gasket

F. Gasket scraper

G. Gasket sealer

H. Torque wrench

I. Radiator fill can

J. V-belt of correct type and size

K. V-belt tension gauge

L. Shop towels

M. Appropriate service manual

II. Procedure for removing and reinstalling water pump

A. Drain cooling system

B. Remove drive belt

C. Remove fan

(NOTE: Usually the fan must be removed before the fan shroud.)

D. Remove fan shroud

E. Determine type of water pump

(NOTE: Some water pumps are small and are attached to the front engine housing. Other pumps are attached to the block and require lower-hose removal.)

JOB SHEET #4

F. Remove lower hose if required

G. Remove water-pump retaining bolts

H. Remove water pump

I. Clean gasket material and rust from pump and housing-gasket surface

J. Apply gasket sealer to gasket surfaces

K. Install new gasket on water pump

(NOTE: Sometimes you must place the gasket on the block for convenience of installation.)

L. Reinstall water pump

M. Start retaining bolts

N. Tighten water-pump retaining bolts uniformly; torque to specifications

O. Reattach lower hose

P. Install fan shroud if used

Q. Install fan assembly

(NOTE: Make sure that fan is placed correctly to draw air through the radiator.)

III. Procedure for removing and reinstalling fan belt

A. Inspect V-belt

(NOTE: Inspect for cracks, glazing, fraying, or any condition that will make the belt unreliable or inefficient to use. Replace if necessary.)

B. Install new belt

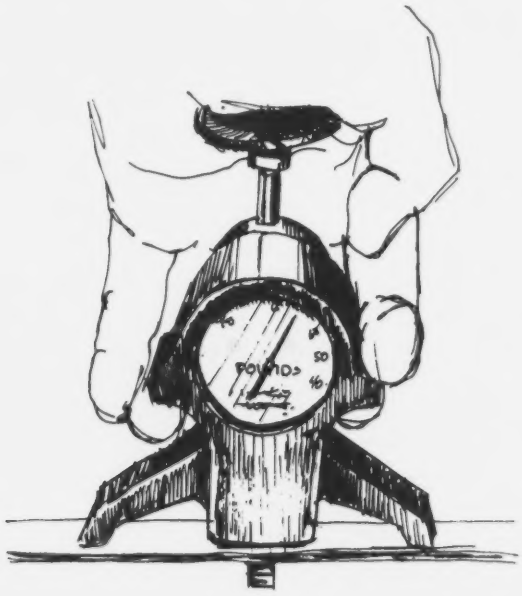
(CAUTION: Be sure that new belt meets manufacturer's specifications.)

JOB SHEET #4

C. Adjust belt tension to manufacturer's specifications (Figure 15)

(NOTE: Tension can also be checked by measuring the amount of belt deflection; check manufacturer's specifications for proper deflection.)

FIGURE 15



D. Hold tension on belt, and tighten all brackets and braces securely

E. Recheck tension

(NOTE: Readjust new belts after a few hours of operation, due to stretching.)

F. Follow manufacturer's recommended procedure for water-pump break-in

G. Close radiator drain

H. Fill radiator with coolant

I. Start engine and allow to warm up

J. Check for leaks

K. Clean work area; clean and put away all tools and equipment

COOLING SYSTEMS
UNIT IV

JOB SHEET #5 — REMOVE AND REINSTALL A RADIATOR

I. Equipment and materials

- A. Vehicle
- B. Drain pan
- C. Basic hand-tool set
- D. Hose-clamp pliers
- E. Air compressor
- F. Safety glasses
- G. Shop towels
- H. Appropriate service manual
- I. Radiator fill can

II. Procedure

- A. Drain radiator
- B. Disconnect upper radiator hose from radiator
- C. Disconnect lower radiator hose from radiator
- D. Remove fan-shroud attaching screws
- E. Move fan shroud toward the engine and over fan assembly
- F. Disconnect automatic-transmission cooler lines if used

  (NOTE: To avoid damage to the fitting and radiator, use a backup wrench when removing lines.)
- G. Remove radiator attaching bolts
- H. Remove radiator
- I. Clean air passages, using compressed air

  (CAUTION: Always wear eye protection when using compressed air.)
- J. Check radiator mounting shell for breaks or cracks
- K. Reinstall radiator

  (NOTE: Make sure that fan shroud is in place before radiator is reinstalled.)

JOB SHEET #5

L. Position radiator; start radiator attaching bolts

M. Tighten attaching bolts

N. Reinstall transmission cooler lines and tighten securely

(NOTE: To prevent damage to fittings and radiator, use a backup wrench when tightening lines.)

O. Move fan shroud into place, install attaching screws, and tighten securely

P. Inspect hoses to determine if replacement is necessary

Q. Install lower hose and tighten clamps securely

R. Install upper hose and tighten clamps securely

S. Close radiator drain cock

T. Refill radiator with recommended coolant

U. Start engine and allow to warm up

V. Check for coolant leaks

W. Check coolant level

X. Clean work area; clean and put away all tools and equipment

COOLING SYSTEMS
UNIT IV

JOB SHEET #6 — TEST ANTIFREEZE SOLUTION

I. Equipment

A. Vehicle

B. Antifreeze hydrometer tester

II. Procedure

A. Start engine and allow time for coolant to warm up to operating temperature

B. Remove radiator cap

(CAUTION: Never remove the radiator cap quickly when the engine is hot. Loosen cap slowly to first stop and leave in this position until all pressure is released. Cap can then be removed safely.)

C. Draw coolant into tester and empty several times to equalize the temperature of all parts

D. Draw coolant into tester

E. Read first number or letter above the liquid surface on float

F. Note temperature of coolant

G. Measure antifreeze content of water by comparing readings with chart on tester

(NOTE: The antifreeze content should be such that the cooling system would be protected to 10 Fahrenheit degrees [5 Celsius degrees] lower than the coldest temperature expected.)

H. Add antifreeze if necessary

(NOTE: When adding antifreeze, allow room for expansion.)

I. Clean work area; put away antifreeze hydrometer tester

COOLING SYSTEMS
UNIT IV

JOB SHEET #7 — TEST FOR EXHAUST-GAS LEAKAGE AND AIR IN THE COOLING SYSTEM

I. Equipment and materials

A. Live engine

B. Rubber tube

C. Bottle of water

D. Safety glasses

II. Procedure

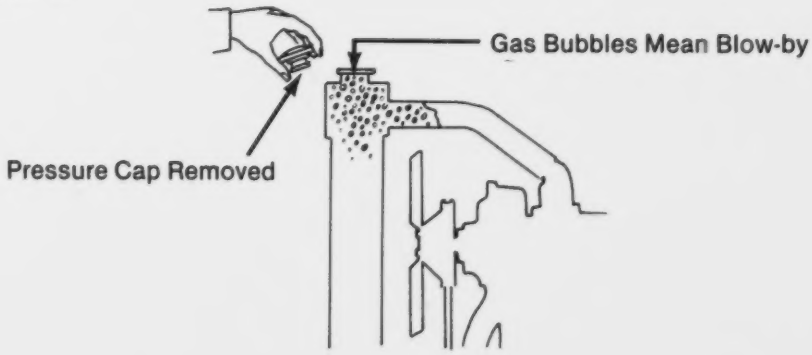
A. Test for exhaust-gas leakage (blow-by)

1. Warm up engine and keep it under load

2. Remove radiator cap, and look for excessive bubbles in coolant (Figure 16)

(CAUTION: Never remove the radiator cap quickly when the engine is hot. Loosen cap slowly to first stop and leave in this position until all pressure is released. Cap can then be removed safely.)

FIGURE 16



3. Look for a sign of blow-by, such as bubbling or an oil film on the coolant

(NOTE: A cracked head or a loose cylinder-head joint allows hot exhaust gas to be blown into the cooling system under combustion pressures, even though the joint may be tight enough to keep liquid from leaking into the cylinder. The cylinder-head gasket itself may be burned and corroded by escaping exhaust gases. Exhaust gases dissolved in coolant destroy the inhibitors and form acids that cause corrosion, rust, and clogging.)

JOB SHEET #7

B. Test for air in cooling system

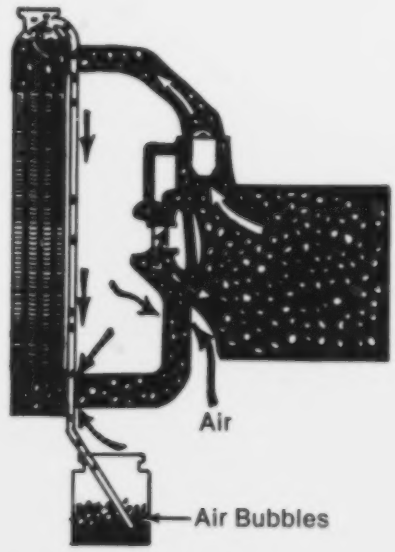
1. Adjust coolant to correct level
2. Replace pressure cap with a plain, airtight cap
3. Attach rubber tube to lower end of overflow pipe

   (NOTE: Be sure that radiator cap and tube are airtight.)

4. With transmission in neutral gear, run engine at high speed until temperature gauge stops rising and remains stationary
5. Without changing engine speed or temperature, put end of rubber tube in bottle of water
6. Watch for continuous stream of bubbles in the water bottle; a continuous stream of bubbles shows that air is being drawn into the cooling system (Figure 17)

   (NOTE: Air may be drawn into the coolant because of a leak in the system, turbulence in the top tank, or too-low coolant level.)

FIGURE 17



C. Clean work area; clean and put away all tools and equipment

COOLING SYSTEMS
UNIT IV

TEST

NAME _____ SCORE _____

1. Match to their correct definitions terms associated with cooling systems. Write the correct numbers in the blanks. Definitions are continued on the next page.

_____a. Device for holding a considerable volume of coolant in close contact with a large amount of air so that heat may be transferred from coolant to air

_____b. Hose used to connect radiator to engine

_____c. Heat-controlled valve in cooling system; used to regulate flow of coolant between cylinder block and radiator

_____d. Cap that increases pressure within cooling system several pounds per square inch; allows coolant to circulate at higher temperatures without evaporation or surge loss

_____e. Centrifugal pump mounted at front of cylinder block; circulates coolant throughout cooling system

_____f. Passage through block and cylinder head that allows coolant to circulate around cylinders, valves, and combustion chambers

_____g. Device mounted on water-pump hub assembly; used to move large amounts of air so that heat may be transferred from coolant to air

_____h. Funnel-like structure attached to radiator, extending around and behind fan; used to make fan more effective in pulling air through radiator

_____i. Belt turned by a pulley on front of crankshaft; used to drive water pump, fan, and other engine accessories

1. Thermostat
2. Water jacket
3. Coolant
4. Aeration
5. Shroud
6. Radiator shutter
7. Radiator hose
8. V-belt
9. Water pump
10. Bimetallic
11. Fan
12. Radiator
13. Pressure cap

TEST

_____j. Liquid that circulates through cooling system to transfer engine heat

_____k. Device over radiator; used to maintain temperature variations of coolant

_____l. Pertaining to two strips of dissimilar metal welded together, one of which expands more when heated than the other

_____m. Process of mixing air and water

2. Describe the purpose of the cooling system.

_____

_____

_____

3. State jobs performed by the cooling system.

a. _____

_____

b. _____

_____

c. _____

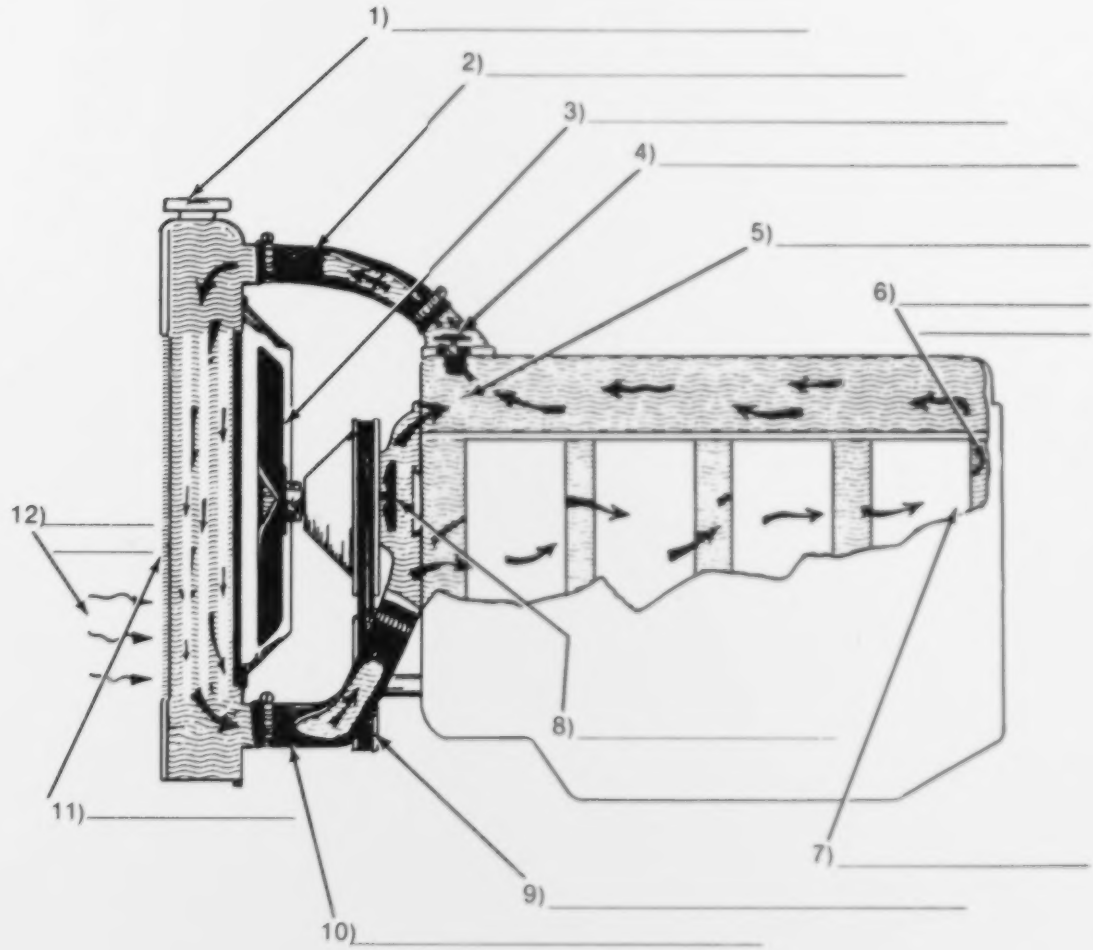
_____

TEST

4. Identify components of gasoline and diesel cooling systems illustrated on this and the next page. Write the correct names in the blanks.

   a. Gasoline

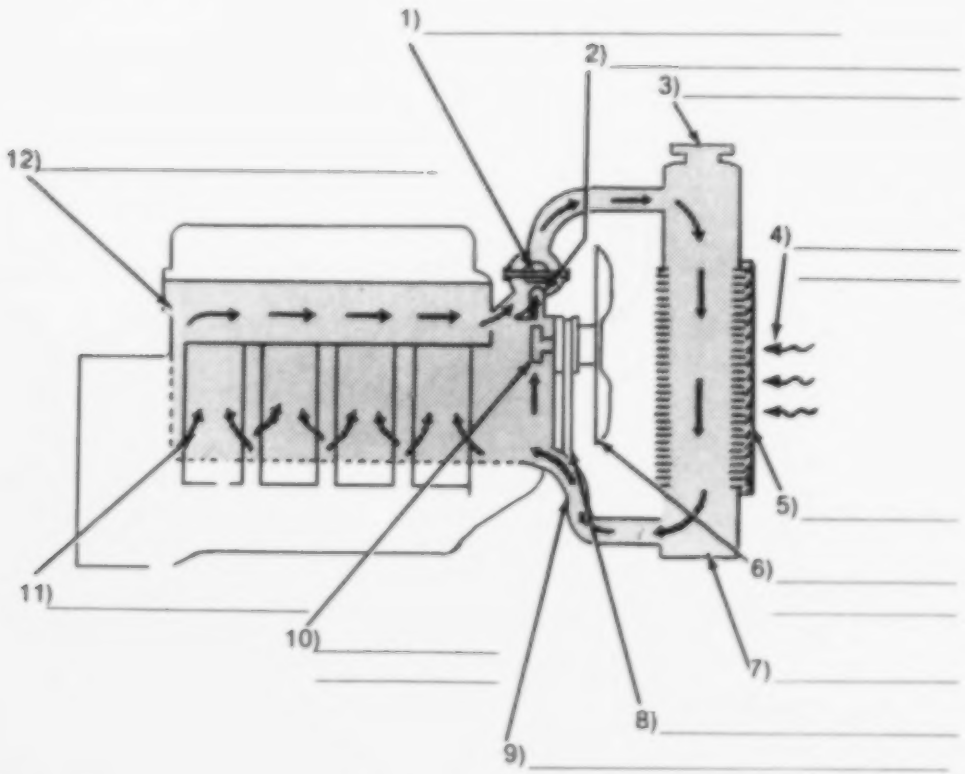
Pressure cap	**Coolant**	**Fan**
Thermostat	**Radiator**	**Fan belt**
Radiator hose	**Engine water jacket**	**Air flow**
Bypass	**Water pump**	



TEST

b. Diesel

Engine water jacket	**Fan belt**	**Shutter**
Radiator hose	**Air flow**	**Fan (reversible)**
Water pump	**Radiator**	**Bypass**
Pressure cap	**Coolant**	
Thermostat		



TEST

5. Distinguish between characteristics of liquid and air cooling systems. Write an "X" in the blank before a liquid cooling system.

_____a. Uses a fan, cooling fins, and shrouding

_____b. Uses circulating coolant

6. Select from the following list types of thermostats. Write an "X" in the blank before each correct answer.

_____a. Liquid

_____b. Bellows

_____c. Air

_____d. Bimetallic

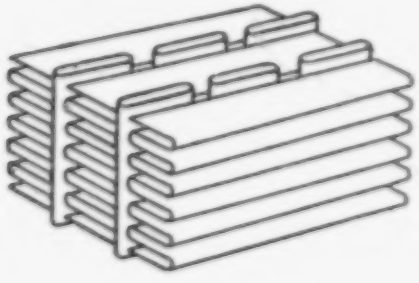
_____e. Pellet

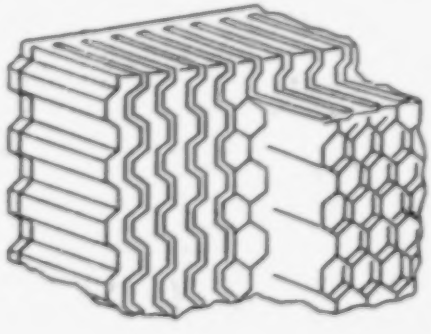
7. Distinguish between thermostat operation in a cold engine and in an engine at operating temperature. Write an "X" in the blank before the engine at operating temperature.

_____a. Thermostat is open and allows coolant to circulate through system

_____b. Thermostat shuts off flow of coolant from engine to radiator to allow quicker engine warm-up

8. Label the two types of radiators illustrated below. Write the correct names in the blanks.





a. _____ b. _____

TEST

9. Distinguish between characteristics of downflow and crossflow radiators. Write a "D" in the blanks before characteristics of a downflow radiator, and a "C" in the blanks before characteristics of a crossflow radiator.

_____a. Has tanks on sides

_____b. Coolant flows from top to bottom

_____c. Coolant flows from side to side across radiator

_____d. Has tanks on top and bottom

10. Describe pressure cap operation at various temperatures.

a. Cooling system at normal temperature — _____

_____

_____

_____

b. Cooling system very hot with built-up excess pressure — _____

_____

_____

c. Cooling system during cooling-off period — _____

_____

_____

_____

11. Name types of fans used in cooling systems.

a. _____

b. _____

c. _____

12. Describe operation of the variable-speed fan drive.

a. _____

_____

b. _____

_____

TEST

13. State reasons for using permanent-type antifreeze in the cooling system.

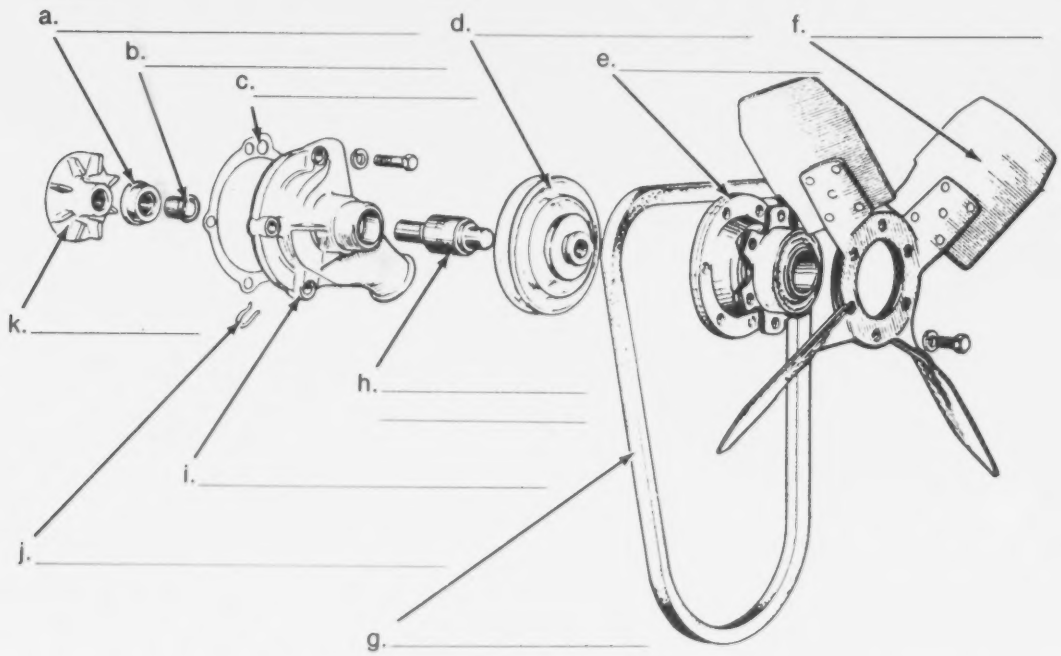
a. _____

b. _____

c. _____

14. Identify basic parts of a water pump and fan. Write the correct names in the blanks.

Fan-blade assembly
Bearing and shaft assembly
Water-pump housing
Gasket
Shaft slinger
Bearing retainer
Impeller
Seal
Fan hub
Pulley
Fan belt



(NOTE: Test question 15 lists the job sheets. They are an important part of this test. If they have not been completed, check with your instructor.)

15. Demonstrate the ability to

a. Remove, check, and reinstall a thermostat.

b. Pressure test the cooling system.

c. Reverse flush a radiator.

TEST

d. Remove and reinstall a water pump and fan belt.

e. Remove and reinstall a radiator.

f. Test antifreeze solution.

g. Test for exhaust-gas leakage and air in the cooling system.

COOLING SYSTEMS
UNIT IV

ANSWERS TO TEST

1.	a.	12	f.	2	k.	6
	b.	7	g.	11	l.	10
	c.	1	h.	5	m.	4
	d.	13	i.	8		
	e.	9	j.	3		

2. Description should include the following

   To keep the engine at its most efficient operating temperature during all engine speeds and operating conditions

3. a. Removing surplus or unwanted heat

   b. Maintaining an efficient temperature under all operating conditions

   c. Bringing engine to operating temperature as soon after starting as possible

4. a. Gasoline

   1) Pressure cap
   2) Radiator hose
   3) Fan
   4) Thermostat
   5) Bypass
   6) Engine water jacket
   7) Coolant
   8) Water pump
   9) Fan belt
   10) Radiator hose

ANSWERS TO TEST

11) Radiator

12) Air flow

b. Diesel

1) Thermostat

2) Bypass

3) Pressure cap

4) Air flow

5) Shutter

6) Fan (reversible)

7) Radiator

8) Fan belt

9) Radiator hose

10) Water pump

11) Coolant

12) Engine water jacket

5. b

6. b, d, e

7. a

8. a. Tube-and-fin-type core

b. Cellular-type core

9. a. C

b. D

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ANSWERS TO TEST

c. C

d. D

10. Description should include the following

a. Cooling system at normal temperature — Pressure cap fits over radiator filler tube and seals tightly around edges to prevent evaporation or surge loss

b. Cooling system very hot with built-up excess pressure — Blow-off valve has calibrated spring that opens to release excess pressure in cooling system

c. Cooling system during cooling-off period — Vacuum valve opens to allow air to enter the cooling system to prevent collapse of radiator and hoses

11. a. Blower

b. Suction

c. Reversible

12. Description should include the following

a. When engine temperatures are high, the fan speed is increased to aid cooling

b. When engine temperatures are low, the fan speed is decreased to conserve engine power

13. a. Prevents coolant from freezing

b. Has a higher boiling point than water

c. Reduces the corrosive action of water

14. a. Seal

b. Shaft slinger

c. Gasket

d. Pulley

e. Fan hub

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ANSWERS TO TEST

f. Fan-blade assembly

g. Fan belt

h. Bearing and shaft assembly

i. Water-pump housing

j. Bearing retainer

k. Impeller

15. Performance skills evaluated to the satisfaction of the instructor

ELECTRICAL SYSTEMS
UNIT V

UNIT OBJECTIVE

After completing this unit, the student should be able to remove, repair, and replace all electrical components of an engine. The student will show this knowledge by completing job sheets and unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match to their correct definitions terms associated with electrical systems.
2. List basic factors of electrical flow in a circuit.
3. Discuss relationship of voltage, amperage, and ohms to current flow.
4. Select from a list factors that affect resistance in a conductor.
5. List components of a basic electrical circuit.
6. Label types of electrical circuits.
7. Identify basic symbols used in electrical systems.
8. Identify instruments used to test electrical circuits.
9. Distinguish between direct current and alternating current.
10. State functions of the battery.
11. State processes by which a battery converts chemical energy into electrical energy.
12. Match types of battery ratings to their correct descriptions.
13. Select from a list safety rules pertaining to care and maintenance of batteries.
14. Match terms associated with starting systems to their correct definitions.
15. State the purpose of the starting system.
16. Label components of the starting system.
17. Match major parts of a starting circuit to their correct functions.

OBJECTIVE SHEET

18. Identify basic parts of a starter.
19. State the purpose of the ignition system.
20. Identify components of the ignition system.
21. Match components of the ignition system to their correct functions.
22. Identify basic components of a distributor.
23. Distinguish between the components of the primary and secondary ignition circuits.
24. Arrange in order the steps of ignition-system operation through one complete cycle, beginning with the battery.
25. Label the parts of a spark plug.
26. Match conditions of spark plugs to their correct causes.
27. Distinguish between transistorized and capacitive-discharge ignition systems.
28. Discuss relationship of an electronic ignition system to a conventional ignition system.
29. List advantages of the electronic ignition system.
30. Identify major components of the electronic ignition system.
31. Match components of the electronic ignition system to their correct functions.
32. Arrange in order the steps in electronic ignition system operation.
33. State the purpose of the charging system.
34. Match terms associated with charging systems to their correct definitions.
35. Match charging-system components to their correct purposes.
36. Identify major parts of a generator.
37. Identify major parts of an alternator.
38. Distinguish between generator and alternator.
39. Label types of stator windings.
40. Describe how current and voltage are regulated in an alternator.
41. Label types of voltage regulators for alternators.

OBJECTIVE SHEET

42. Label parts of a glow plug.

43. Discuss glow plug operation.

44. Demonstrate the ability to

    a. Construct a series circuit.

    b. Construct a parallel circuit.

    c. Clean and service a battery.

    d. Remove and replace a battery.

    e. Measure battery electrolyte with a hydrometer.

    f. Load test a battery.

    g. Charge test a battery for three minutes.

    h. Start engine using a negative-ground booster battery.

    i. Use a 24-volt battery-booster system to start a vehicle with a 12-volt system.

    j. Load test a starter.

    k. Test starter-circuit resistance.

    l. Test starter control-circuit resistance.

    m. Remove and replace a starter.

    n. Disassemble, check, and reassemble a starter.

    o. Check and set ignition timing.

    p. Remove and replace a distributor.

    q. Remove and replace contact points and condenser.

    r. Adjust dwell on an externally adjustable distributor.

    s. Test and adjust distributor on distributor tester.

    t. Remove, inspect, service, and replace spark plugs.

    u. Remove and replace a generator.

    v. Disassemble, check, and reassemble a generator.

OBJECTIVE SHEET

w. Remove and replace an alternator.

x. Disassemble, check, and reassemble an alternator.

y. Test alternator charging-circuit resistance.

z. Test alternator current output.

aa. Test external-type voltage regulator.

bb. Test internal-type voltage regulator on vehicle.

ELECTRICAL SYSTEMS
UNIT V

SUGGESTED ACTIVITIES

I. Suggested activities

A. Order films and other materials planned to supplement unit.

(NOTE: Manufacturers are excellent sources for slide and film presentations on electrical systems. Write directly to the appropriate company or manufacturer.)

B. Gather material and equipment for job sheet demonstrations.

C. Check with manufacturers and local equipment dealers for visual aids to demonstrate electrical-system operations.

D. Obtain transparencies.

(NOTE: Transparencies are available from AGC and CIMC.)

E. Provide students with objective sheet.

F. Discuss unit and specific objectives.

G. Provide students with information and job sheets.

H. Discuss information sheet.

I. Demonstrate and discuss procedures outlined in job sheets.

J. Give test.

K. Complete appropriate section of competency profiles.

(NOTE: Competency profiles are available from AGC and CIMC.)

II. Instructional materials

A. Objective sheet

B. Suggested activities

C. Information sheet

D. Transparency masters

1. TM #1 — Basic Electrical Circuit

SUGGESTED ACTIVITIES

2. TM #2 — Types of Electrical Circuits
3. TM #3 — Current and Electrolyte
4. TM #4 — Components of the Starting System
5. TM #5 — Operation of the Ignition System - A
6. TM #6 — Operation of the Ignition System - B
7. TM #7 — Operation of the Ignition System - C
8. TM #8 — Operation of the Ignition System - D
9. TM #9 — Operation of the Ignition System - E
10. TM #10 — Spark Plug Conditions
11. TM #11 — Operation of Electronic Ignition System
12. TM #12 — Difference Between Generator and Alternator

E. Job sheets

1. Job Sheet #1 — Construct a Series Circuit
2. Job Sheet #2 — Construct a Parallel Circuit
3. Job Sheet #3 — Clean and Service a Battery
4. Job Sheet #4 — Remove and Replace a Battery
5. Job Sheet #5 — Measure Battery Electrolyte with a Hydrometer
6. Job Sheet #6 — Load Test a Battery
7. Job Sheet #7 — Charge Test a Battery for Three Minutes
8. Job Sheet #8 — Start an Engine Using a Negative-Ground Booster Battery
9. Job Sheet #9 — Use a 24-Volt Battery-Booster System to Start a Vehicle with a 12-Volt System
10. Job Sheet #10 — Load Test a Starter
11. Job Sheet #11 — Test Starter-Circuit Resistance
12. Job Sheet #12 — Test Starter Control-Circuit Resistance

SUGGESTED ACTIVITIES

13. Job Sheet #13 — Remove and Replace a Starter
14. Job Sheet #14 — Disassemble, Check, and Reassemble a Starter
15. Job Sheet #15 — Check and Set Ignition Timing
16. Job Sheet #16 — Remove and Replace a Distributor
17. Job Sheet #17 — Remove and Replace Contact Points and Condenser
18. Job Sheet #18 — Adjust Dwell on an Externally Adjustable Distributor
19. Job Sheet #19 — Test and Adjust Distributor on Distributor Tester
20. Job Sheet #20 — Remove, Inspect, Service, and Replace Spark Plugs
21. Job Sheet #21 — Remove and Replace a Generator
22. Job Sheet #22 — Disassemble, Check, and Reassemble a Generator
23. Job Sheet #23 — Remove and Replace an Alternator
24. Job Sheet #24 — Disassemble, Check, and Reassemble an Alternator
25. Job Sheet #25 — Test Alternator Charging-Circuit Resistance
26. Job Sheet #26 — Test Alternator Current Output
27. Job Sheet #27 — Test External-Type Voltage Regulator
28. Job Sheet #28 — Test Internal-Type Voltage Regulator on Vehicle

F. Test

G. Answers to test

III. Unit references

A. Armstrong, Ivan J. *Auto Mechanics, Vol. II.* Stillwater, Oklahoma: State Department of Vocational and Technical Education/Curriculum and Instructional Materials Center, 1978.

B. Grob, Bernard. *Basic Electronics,* 4th ed. New York: McGraw-Hill Book Company, 1977.

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ELECTRICAL SYSTEMS
UNIT V

INFORMATION SHEET

I. Terms and definitions associated with electrical systems

A. Alternating current (AC) — Flow of electrons in a conductor that reverses direction of flow at intervals

B. Ampere (A) — Standard unit for measuring the strength of an electric current; rate of flow or charge in a conducting medium of 1 coulomb per second

C. Circuit — Continuous path along a conductor through which electrical current can flow from a source, through a load, and back to the source

D. Conductor — Any material that allows electrical current to flow through it easily

E. Coulomb (coul) — Charge transported through a conductor by a current of 1 ampere flowing for one second; legal standard of electricity

F. Current (I) — Flow of electrons measured in amperes; flow of electrical charge

G. Direct current (DC) — Steady flow of electrons moving continually in the same direction along a conductor from a point of high potential to one of lower potential

H. Dwell — Number of degrees of distributor-cam rotation that the ignition points are closed

I. Electromotive force (emf) — Force that tends to cause a flow of electricity that is measured in volts

J. Electronic ignition system — System that uses a control unit and magnetic pickup to open and close the primary circuit

K. Insulator — Material that resists the flow of electrical current

L. Joule (J) — Newton unit of energy; amount of work done by 1 newton acting through a distance of 1 meter and equal to 10,000 ergs

M. Load (L) — Object that converts electrical energy into heat, light, or mechanical energy

N. Newton (N) — Unit of force in the meter-kilogram-second (mks) system

INFORMATION SHEET

O. Ohm (Ω) — Unit of electrical resistance equal to the resistance through which a current of 1 ampere will flow when there is a potential difference of 1 volt across it

P. Polarity — Collective term applied to the positive and negative ends of a magnet or the direction of current flow in a circuit

Q. Resistance (R) — Property of a conductor by which it opposes the flow of an electric current, resulting in generation of heat in conducting material

R. Volt (V) — Unit of potential difference of electromotive force equal to the potential difference between two points for which 1 coulomb of electricity will do 1 joule of work in going from one point to another

S. Voltage (V) — Potential difference or electromotive force measured in volts

II. Basic factors of electrical flow in a circuit

A. Current

(NOTE: Current is measured in amperes.)

B. Voltage

(NOTE: Voltage is measured in volts.)

C. Resistance

(NOTE: Resistance is measured in ohms.)

III. Relationship of voltage, amperage, and ohms to current flow

A. Voltage — Difference in electrical pressure measured between two points in a circuit

B. Amperage — Rate of electron flow

(NOTE: One ampere is 6.28 billion electrons passing a certain point in the conductor in one second.)

C. Ohms — Opposition (resistance) to current flow

IV. Factors that affect resistance in a conductor

A. Material

(NOTE: Some conductor materials have more resistance than others.)

INFORMATION SHEET

B. Cross section (size of conductor)

(NOTE: The larger the cross section, the lower the resistance will be.)

C. Length

(NOTE: The longer the conductor, the higher the resistance will be.)

D. Temperature

(NOTE: With most materials, the higher the temperature, the greater the resistance will be.)

V. Components of a basic electrical circuit (Transparency #1)

A. Source

B. Conductor

C. Load

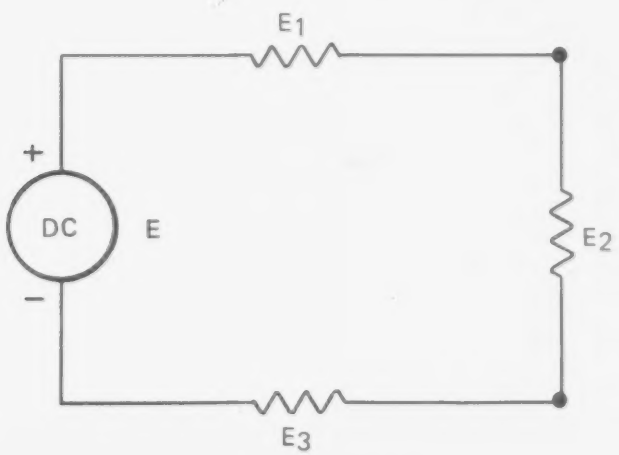
D. Switch

VI. Types of electrical circuits (Figures 1-3; Transparency #2)

A. Series

(NOTE: In a series circuit, the sum of the voltages across the several parts is equal to the total voltage applied to the circuit.)

FIGURE 1



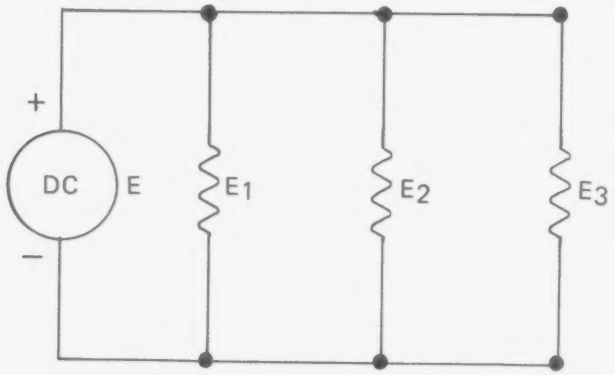
$E = E_1 + E_2 + E_3$

INFORMATION SHEET

B. Parallel

(NOTE: The voltage across each branch of a parallel circuit is the same as the voltage applied to the entire circuit.)

FIGURE 2

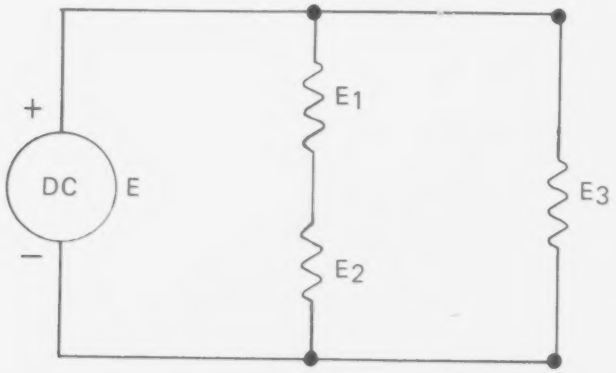


$E = E_1 = E_2 = E_3$

C. Series-parallel

(NOTE: This circuit is a combination of a series circuit and a parallel circuit. It has medium resistance.)

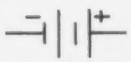
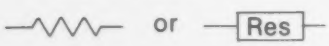
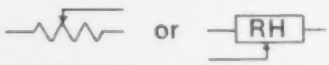
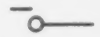
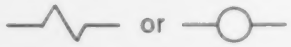
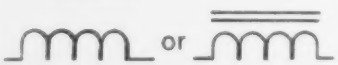
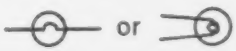
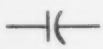
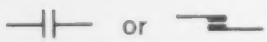
FIGURE 3



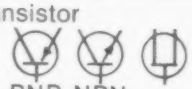
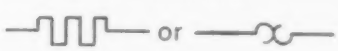
$E = E_1 + E_2 = E_3$

INFORMATION SHEET

VII. Basic symbols used in electrical systems

Battery 	Fixed resistor 
Positive terminal	Variable resistor 
Negative terminal 	Coil 
Ground	Inductor 
Lamp 	Condenser (capacitor) 
Fuse	Spark gap
Circuit breaker	Contact points 
Fusible link or wire	Alternator
Switch (open)	Motor (DC)
Switch (closed)	Diode (one-way)
Voltmeter	Zener diode

INFORMATION SHEET

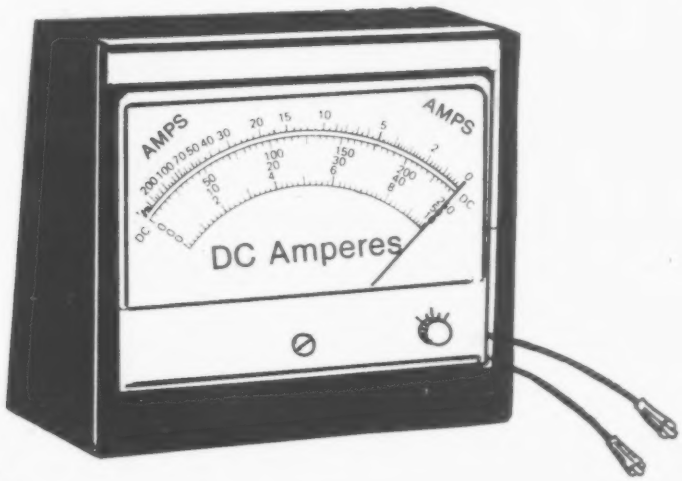
Ammeter	Transistor  PNP NPN
Ohm Ω	Thermal element 

VIII. Instruments used to test electrical circuits (Figures 4-6)

A. Ammeter

(NOTE: The ammeter measures volume of electrical flow in a circuit.)

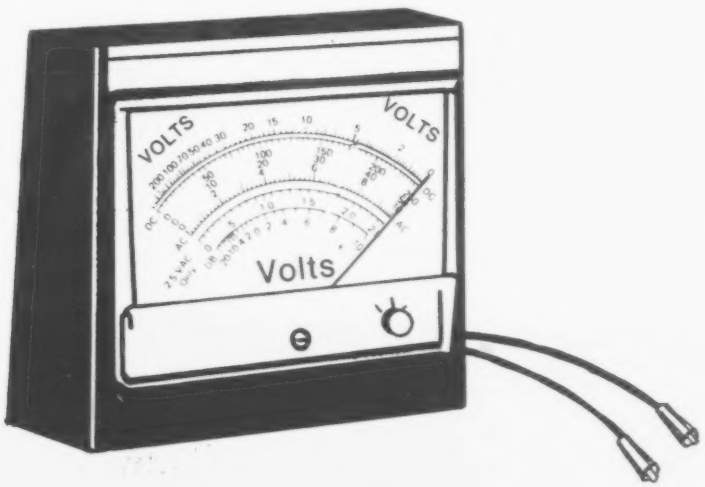
FIGURE 4



B. Voltmeter

(NOTE: The voltmeter measures electrical pressure.)

FIGURE 5

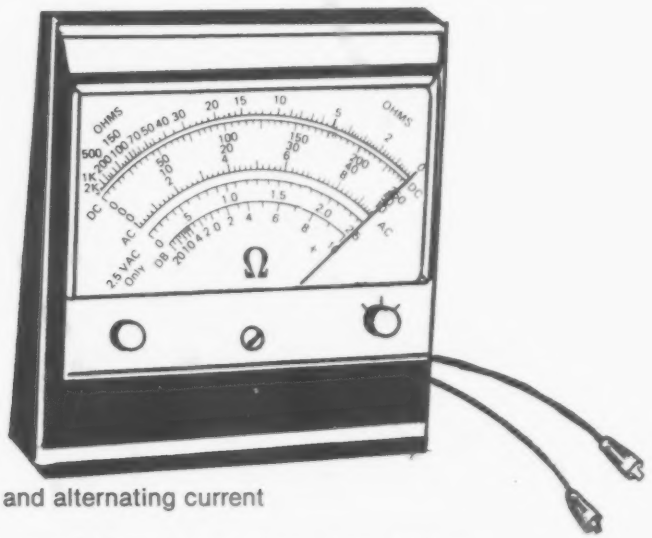


INFORMATION SHEET

C. Ohmmeter

(NOTE: The ohmmeter measures resistance to electrical flow in a circuit.)

FIGURE 6



IX. Direct current and alternating current

A. Direct current (DC) — Flows in one direction only

(NOTE: Current is supplied by a generator or a wet- or dry-cell battery.)

B. Alternating current (AC) — Flows in one direction; then reverses and flows in opposite direction

(NOTE: Current is supplied by an AC generator [alternator].)

X. Functions of the battery

A. Supplies current for cranking engine

B. Supplies current when demand exceeds output of charging system

C. Stabilizes voltage in system during operation

INFORMATION SHEET

XI. Processes by which a battery converts chemical energy into electrical energy (Transparency #3)

A. Two dissimilar metals placed in acid solution produce chemical action

B. The more active metal loses electrons and becomes positively charged

C. The less active metal accumulates electrons and becomes negatively charged

XII. Types of battery ratings

A. Ampere/hour rating (reserve capacity rating) — Length of time in minutes that a fully charged battery at 80°F (26.7°C) can deliver a specified quantity of current

EXAMPLE: 20 amperes for 120 minutes

$$20 \times \frac{120}{60} = 40 \text{ ampere/hour units}$$

B. Cold-cranking rating — Number of amperes that a battery can deliver for thirty seconds at 0°F (17.8°C) without the cell voltage dropping below 1.2 volts

C. Peak watt rating (PWR) — Measure of the battery's cold-cranking ability determined by multiplying the maximum current by the maximum voltage the battery is capable of producing

(NOTE: The numerical rating is embossed on the case at the base of the battery.)

(CAUTION: The peak watt rating should not be confused with the ampere/hour rating since two batteries with the same ampere/hour rating could have quite different watt ratings.)

XIII. Safety rules pertaining to care and maintenance of batteries

A. Do not allow battery electrolyte to come into contact with clothing, skin, eyes, or painted surfaces

B. Keep flames and sparks away from battery because gases given off by battery are very explosive

(NOTE: Gases given off are hydrogen and oxygen.)

C. Avoid shorting or grounding battery terminals during service

D. Wear safety goggles, rubber gloves, and rubber apron when servicing battery

INFORMATION SHEET

E. Flush immediately with water any area of skin that acid has contacted

F. Avoid breathing fumes from battery that is being charged

XIV. Terms and definitions associated with starting systems

A. Armature — Series of loops of wire arranged around a shaft and made to rotate due to magnetic action

B. Brush — Sliding contact used to pass electrical current to a rotating armature

C. Commutator — Device for reversing the direction of current flowing through the conductors of the rotating armature in a motor

D. Field coil — Coil or winding in a generator or starter; produces a magnetic field as current passes through it

E. Pole shoe — Solid or laminated metal core inside a field coil; used to concentrate the magnetic lines of force to produce a strong magnet

F. Solenoid — Tubular field coil with a movable metal core used to engage the starter drive with the flywheel and to close the starter switch

G. Frame — Housing for starter and mounting for field coils and pole shoes

H. Starter drive — Device used to transmit power produced in starter to engine

XV. Purpose of the starting system — To convert electrical energy from battery into mechanical energy at starter in order to crank engine

XVI. Components of the starting system (Transparency #4)

A. Battery

(NOTE: The battery is the source of electrical power.)

B. Key switch

(NOTE: The key switch activates the starter switch.)

C. Starter switch

(NOTE: The starter switch closes the heavy circuit from battery to starter.)

D. Starter

(NOTE: The starter drives the flywheel to crank the engine.)

INFORMATION SHEET

E. Small-gauge switch wire

(NOTE: The wire carries a low amount of current to energize the starter switch.)

F. Battery cable

(NOTE: The cable carries large amounts of current to operate the starter.)

XVII. Functions of major parts of a starting circuit

A. Battery — Supplies energy for the circuit

B. Starter switch — Activates the circuit

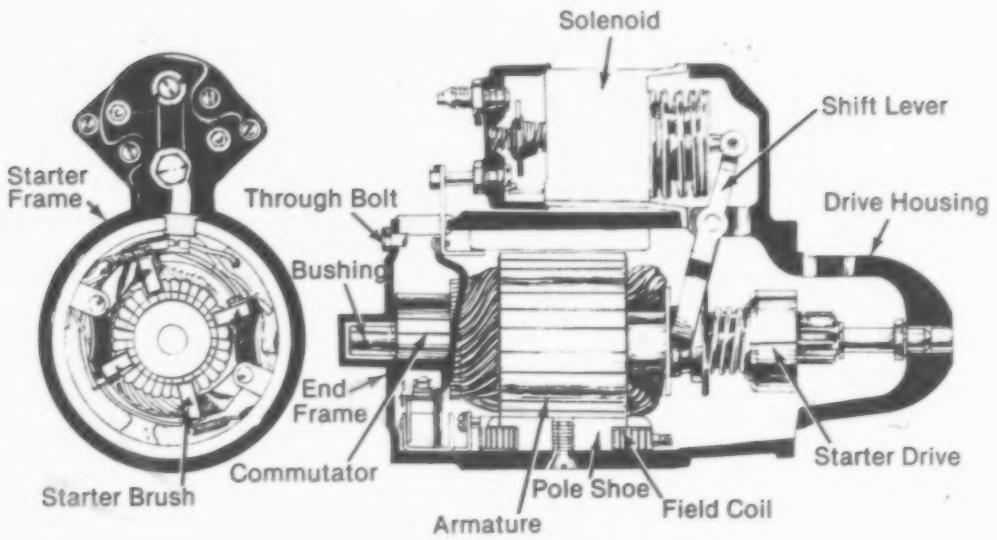
C. Motor switch — Closes circuit to motor and engages motor drive with flywheel

D. Starting motor — Drives flywheel to start engine

INFORMATION SHEET

XVIII. Basic parts of a starter (Figure 7)

FIGURE 7

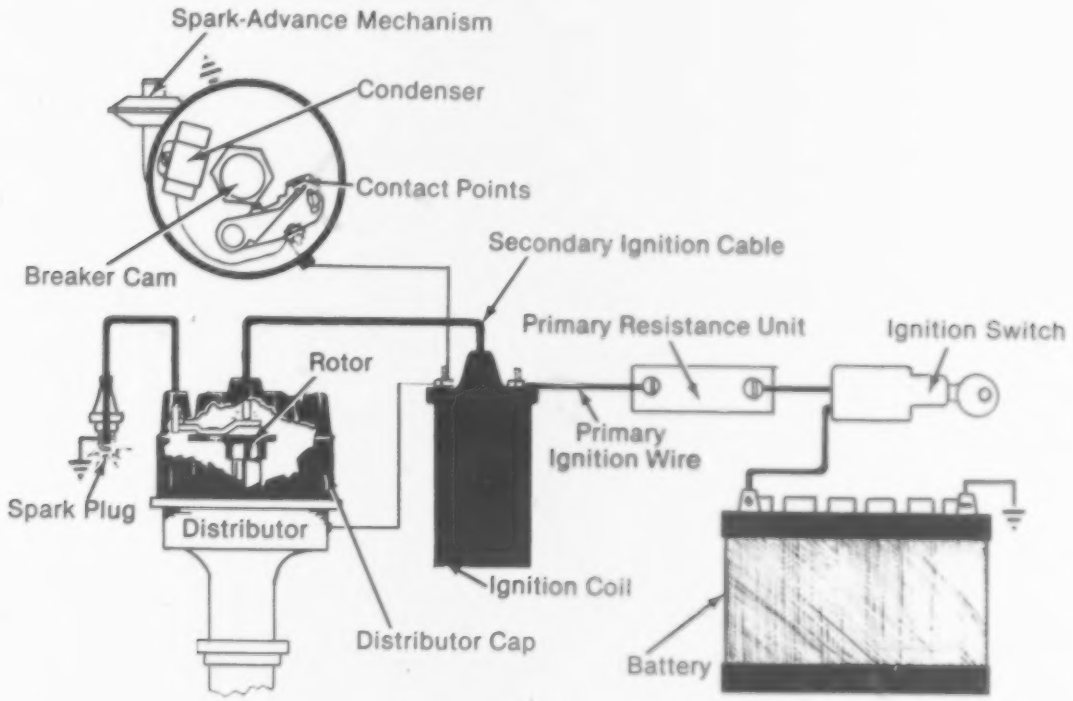


XIX. Purpose of the ignition system — To provide a high-voltage spark to ignite the fuel/air mixture in the combustion chamber

INFORMATION SHEET

XX. Components of the ignition system (Figure 8)

FIGURE 8



XXI. Functions of the components of the ignition system (Transparency #7)

A. Battery — Serves as a source of electrical power

B. Ignition switch — Opens and closes primary circuit from battery to coil

C. Resistance unit — Reduces voltage in primary circuit to protect contact points

(NOTE: Resistor bypass operates only while cranking engine.)

D. Ignition coil — Transforms low voltage into high voltage necessary to jump the spark-plug gap

E. Contact point — Makes and breaks the primary circuit to allow coil to produce high voltage at the spark plugs

(NOTE: Contact points are also known as *breaker points*.)

INFORMATION SHEET

F. Condenser — Stores extra current as the contact points open to prevent arcing and burning; aids coil primary winding to build up magnetic field by releasing its charge back into the circuit as the points close

G. Distributor — Contains the contact points and condenser; distributes the high-voltage current from coil to proper cylinder

H. Breaker cam — Opens and closes contact points

I. Spark-advance mechanism — Regulates timing of high-voltage circuit for best ignition during all speed and load conditions

(NOTE: There are two types of spark-advance mechanisms: vacuum and mechanical. Engine vacuum controls timing advance in relation to engine load. Mechanical advance changes engine timing according to engine speed.)

J. Rotor — Takes high-voltage current from coil and directs it to correct cylinder

K. Distributor cap — Holds coil and spark-plug wires in sequence and provides a cover for distributor

L. Spark plug — Provides a spark gap inside engine cylinder to ignite fuel/air mixture

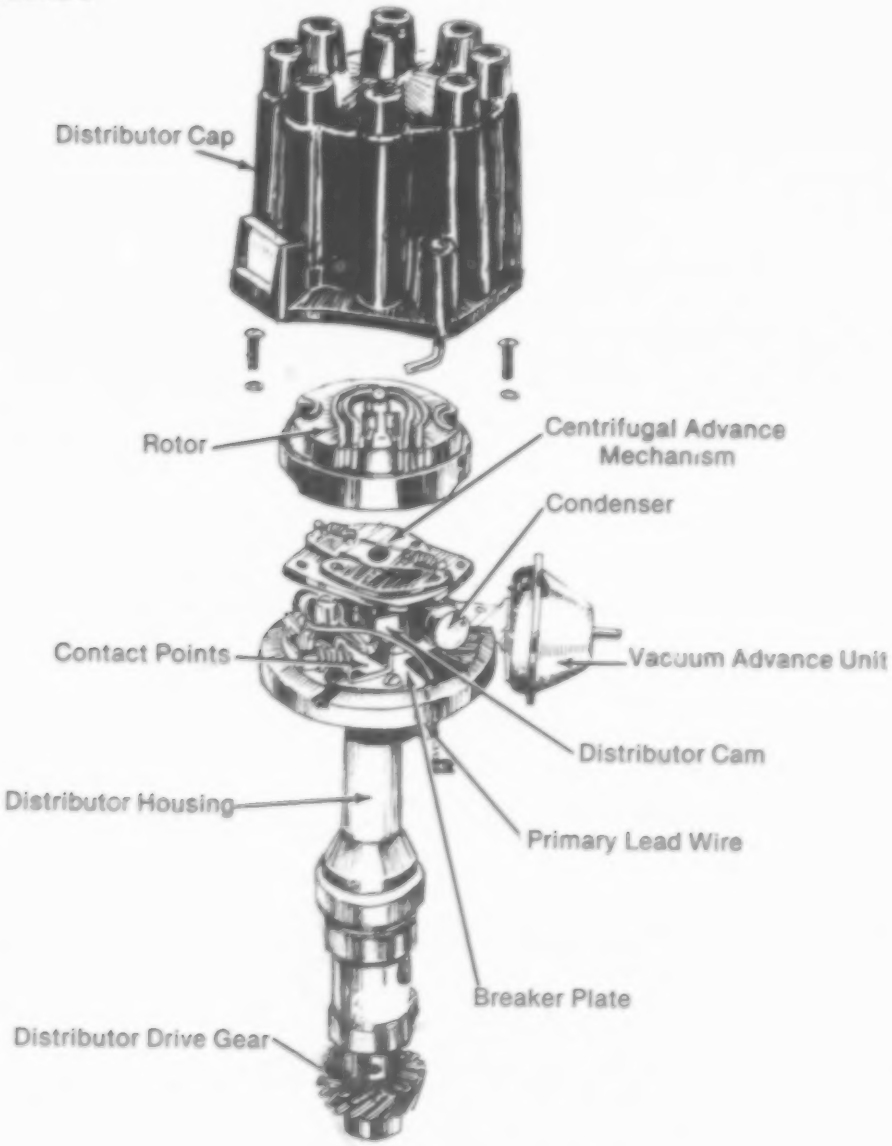
M. Primary ignition wire — Carries low voltage from battery to primary winding of ignition coil (light wire)

N. Secondary ignition cable — Carries high voltage from secondary winding of coil to spark plug (heavy insulated wire)

INFORMATION SHEET

XXII. Basic components of a distributor (Figure 9)

FIGURE 9

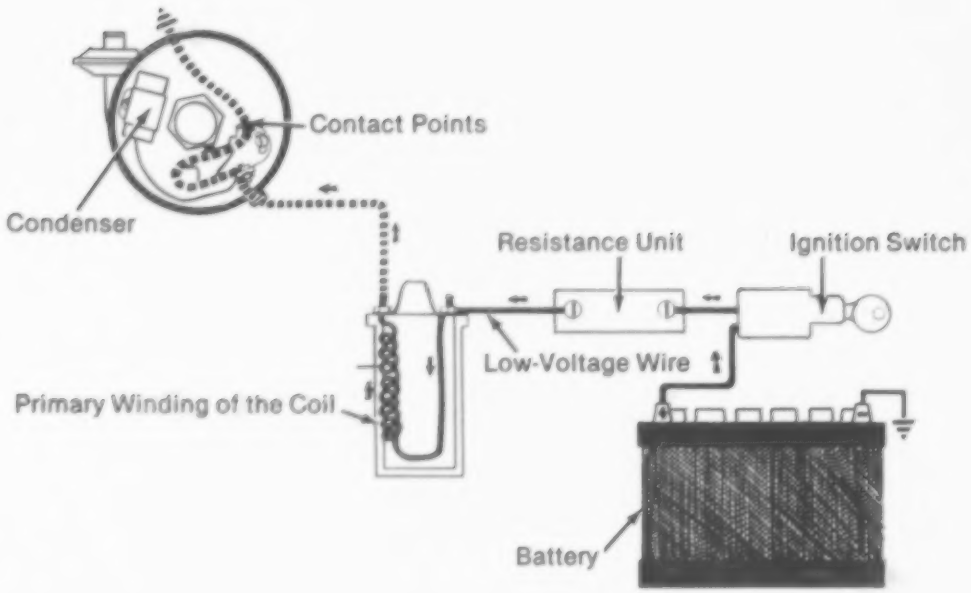


INFORMATION SHEET

XXIII. Components of the primary and secondary ignition circuits (Figures 10 and 11)

A. Primary ignition circuit

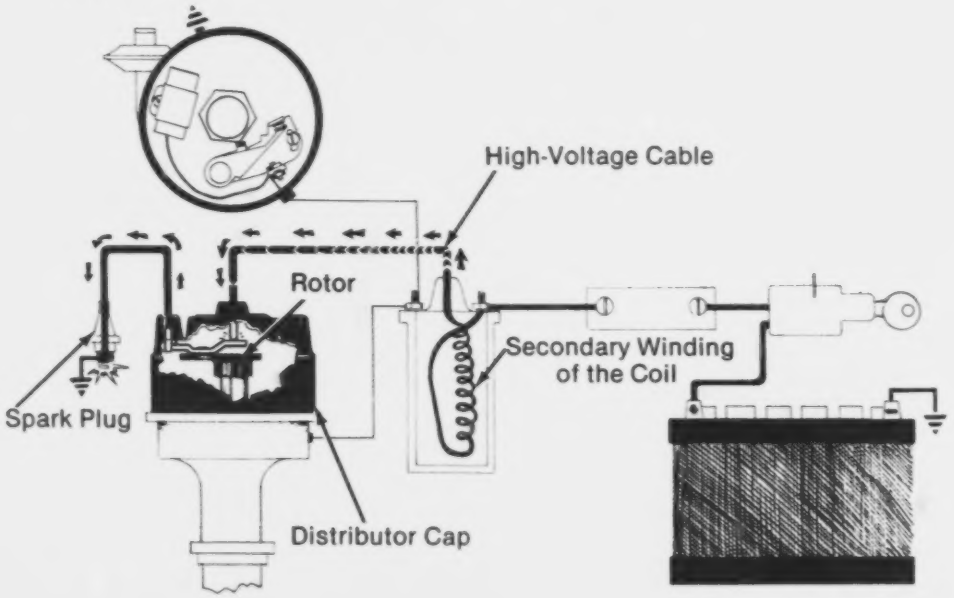
FIGURE 10



INFORMATION SHEET

B. Secondary ignition circuit

FIGURE 11



XXIV. Operation of the ignition system (Transparencies #5-#9)

A. With ignition switch on and contact points closed, low-voltage current flows from battery through primary winding of the coil and through contact points to ground

B. The flow of low-voltage current through primary winding of coil causes a magnetic-field buildup

C. As contact points open, current continues to flow across the point surfaces; condenser attached to points absorbs this flow of current

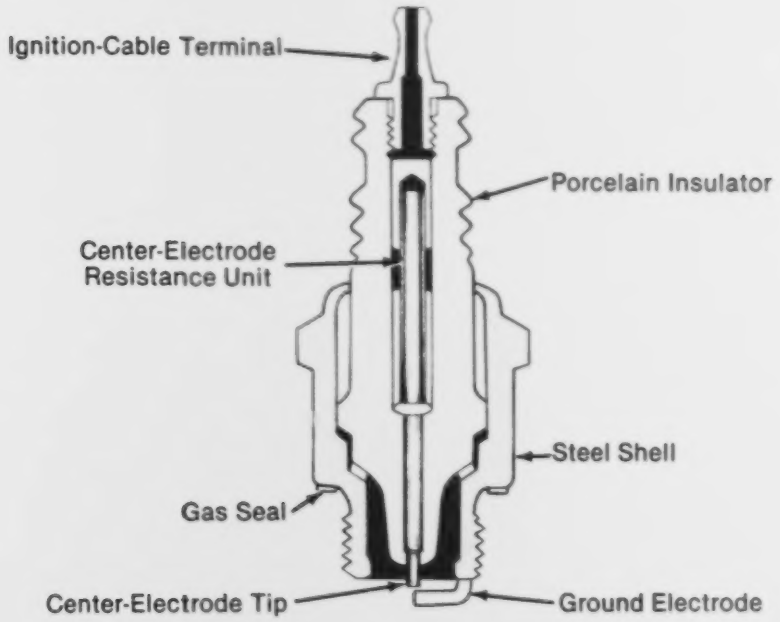
D. Stopping this flow of current causes magnetic field of coil primary winding to collapse across the secondary coil winding, causing a high-voltage surge

E. This high-voltage surge is directed from secondary winding of coil through distributor cap and rotor and on to spark plug to ground

INFORMATION SHEET

XXV. Parts of a spark plug (Figure 12)

FIGURE 12



XXVI. Spark-plug conditions and causes (Transparency #10)

A. Normal — Insulator is brown to grayish tan with slight electrode wear

B. Carbon deposits — Dry deposits indicate rich mixture or weak ignition

C. Oil deposits — Condition is caused by poor oil control; oil is leaking past worn valve guides or piston rings into combustion chamber

D. Too hot — Spark plug will not have deposits, but the porcelain will be white and blistered with center electrode eroded

E. Preignition — Spark plug will have melted electrodes with center electrode generally melting first and ground electrode following

F. High-speed glazing — Insulator has a yellowish, varnishlike color indicating that combustion-chamber temperatures have risen suddenly during hard, fast acceleration

INFORMATION SHEET

G. Modifier deposits — Powdery white or yellow deposits that build up on shell, insulator, and electrodes; this is a normal appearance with certain brands of fuels

H. Splashed deposits — Spotted deposits occur shortly after long-delayed tune-up

XXVII. Transistorized and capacitive-discharge ignition systems

(NOTE: Both variations are designed to increase primary voltage to coil and reduce voltage at points.)

A. Transistorized ignition system

1. Amplifier is included in circuit between points and ignition coil

2. Transistors allow very low voltage through points and battery to primary winding in coil

B. Capacitive-discharge ignition system

1. System contains special ignition distributor, amplifier, and coil

2. System operates to charge a capacitor to a high voltage that, on signal from distributor, is then discharged through primary winding in coil

XXVIII. Relationship of an electronic ignition system to a conventional ignition system — The electronic ignition system functions the same as the conventional system; however, in the electronic system, an electric control unit and its sensory device, a magnetic pickup, do the job of the ignition points in a conventional system

XXIX. Advantages of the electronic ignition system

A. Requires much less maintenance during life of vehicle

B. Has no moving parts in primary circuit

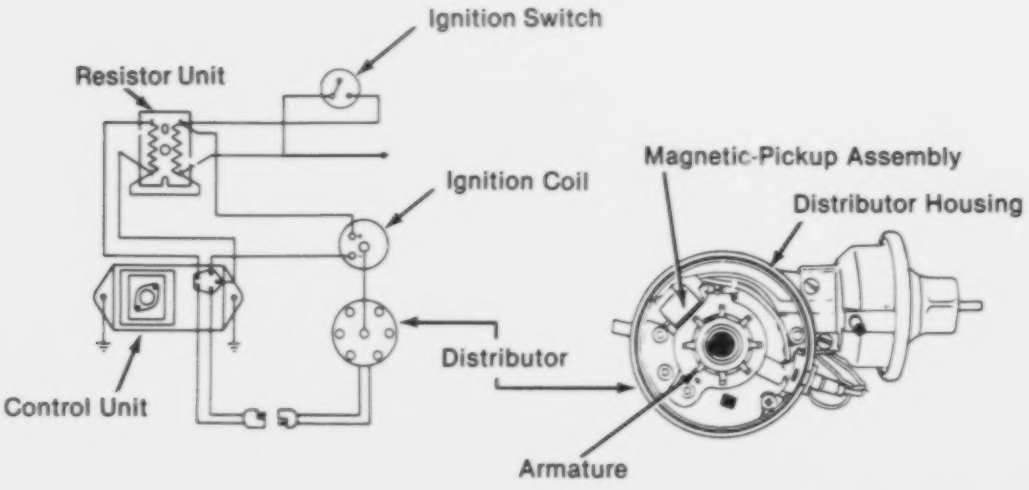
C. Maintains a constant dwell at all engine speeds and operating conditions

D. Extends the efficient life of the spark plugs

INFORMATION SHEET

XXX. Major components of the electronic ignition system (Figure 13)

FIGURE 13



XXXI. Functions of the components of the electronic ignition system (Transparency #11)

A. Resistor unit — Maintains constant primary current with variations in engine speed

(NOTE: The resistor unit is bypassed during engine starting. This component may not be used in all systems.)

B. Control unit — Controls flow of current in primary winding of ignition coil and maintains dwell

C. Magnetic-pickup assembly — Sends a small voltage pulse to the control unit to trigger switching transistor to stop current flow in coil primary winding

D. Armature — Rotates with distributor shaft, producing a voltage pulse in magnetic pickup

(NOTE: The armature is sometimes called a *reluctor* or *timer core* .)

INFORMATION SHEET

XXXII. Steps in electronic ignition system operation (Transparency #11)

A. With ignition switch on and armature tooth not aligned with magnetic pickup, primary circuit has current flowing from ignition switch to resistor unit (if used), through primary winding of coil, through control unit to ground

B. As armature tooth approaches magnetic pickup, voltage begins to build in magnetic-pickup circuit

C. As armature tooth aligns with magnetic pickup, voltage in magnetic-pickup circuit is sufficient to signal switching transistor to shut off current flow in primary circuit

(NOTE: This process is the equivalent of the points opening on a conventional ignition.)

D. With primary circuit open, magnetic field in coil collapses and induces a high-voltage surge in secondary circuit

(CAUTION: To prevent damage to the control unit, the ignition switch should be in the OFF position when making repairs to the electronic ignition system.)

XXXIII. Purpose of the charging system — To recharge the battery and maintain a supply of electrical current to meet the operating needs of the vehicle

XXXIV. Terms and definitions associated with charging systems

A. Diode — Device that allows current to flow in one direction and blocks current in opposite direction

B. Grounded circuit — Circuit in which a wire touches ground, causing current to flow to ground instead of through circuit

C. Open circuit — Circuit in which a wire is broken or disconnected

D. Phase — Stator winding with a positive and negative diode

(NOTE: Alternators are of the three-phase type containing three windings and six diodes.)

E. Rated output — Maximum DC amperage an alternator can produce

F. Rectifier — Group of diodes that converts alternating current to direct current

G. Short circuit — Wire touching another wire and providing a shorter path for current to flow

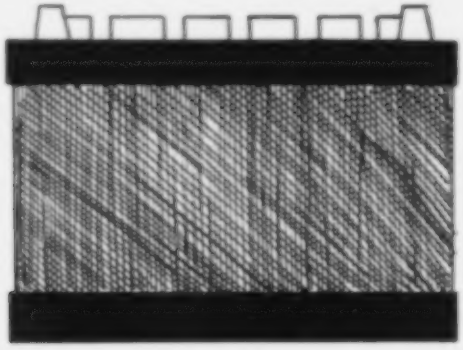
INFORMATION SHEET

XXXV. Purposes of charging-system components (Figures 14 - 18)

A. Battery — Supplies electrical power for starting and operating electrical system during slow generator speed or heavy electrical load

EXAMPLE:

FIGURE 14

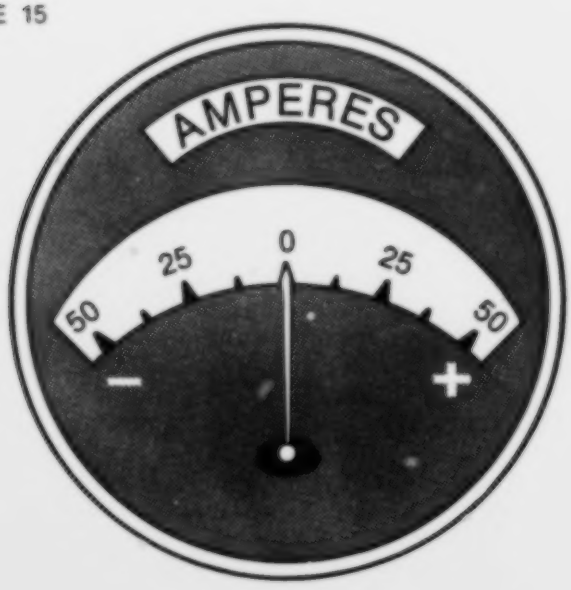


B. Ammeter — Measures rate of current flow

(NOTE: An indicator light replaces ammeter on some models.)

EXAMPLE:

FIGURE 15

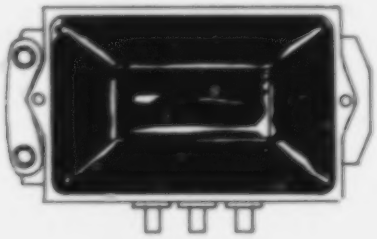


INFORMATION SHEET

C. Regulator — Controls generator voltage and current output

EXAMPLE:

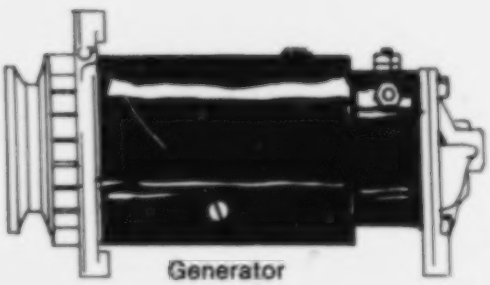
FIGURE 16



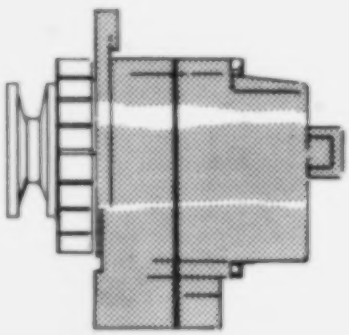
D. Generator or alternator — Supplies electricity to battery and electrical system when driven mechanically by engine

EXAMPLE:

FIGURE 17



Generator



Alternator

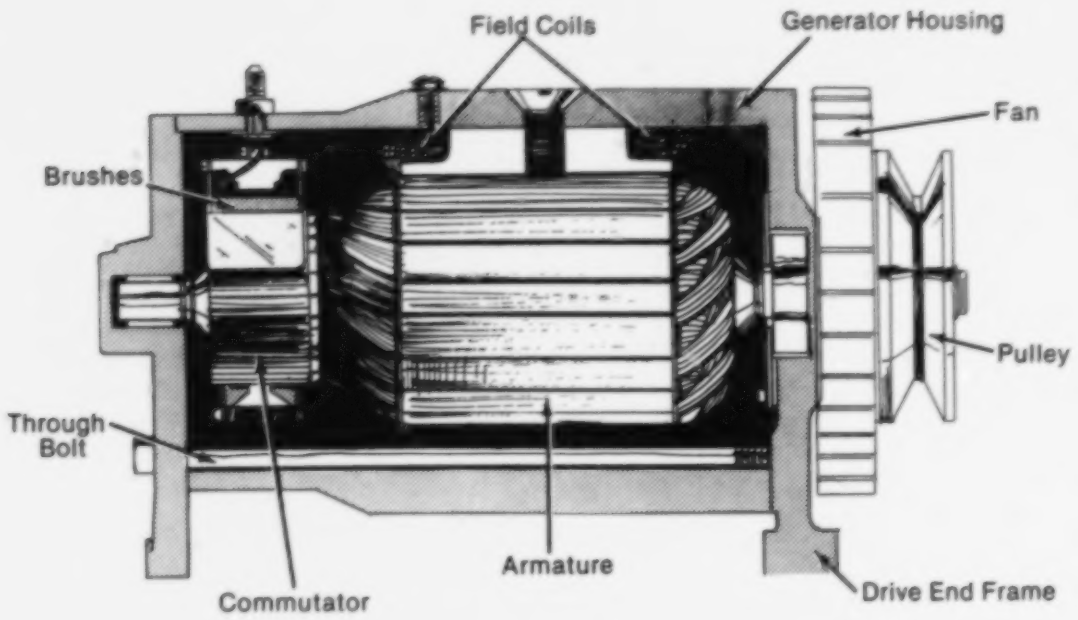
INFORMATION SHEET

E. Indicator light — Indicates a "no charge" condition in charging system

(NOTE: Indicator light replaces ammeter on some models.)

XXXVI. Major parts of a generator (Figure 18)

FIGURE 18

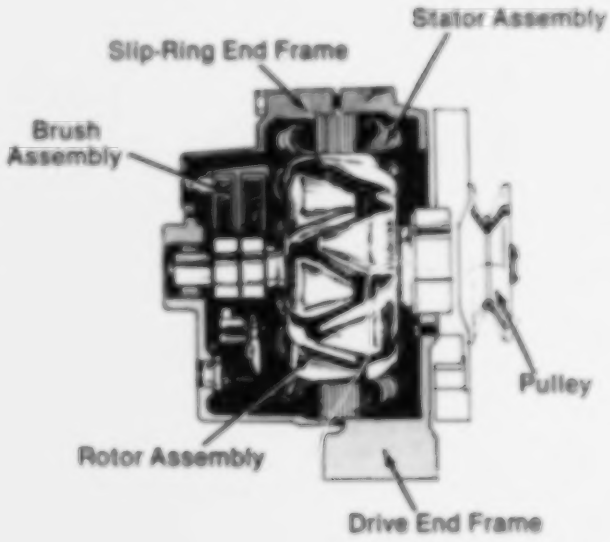


INFORMATION SHEET

XXXVII. Major parts of an alternator (Figures 19 and 20)

FIGURE 19

FIGURE 20



XXXVIII. Differences between generator and alternator (Transparency #12)

A. Generator

1. Rotates armature windings inside field

2. Rectifies current through use of a segmented commutator and brushes

B. Alternator

1. Rotates field inside stationary windings

2. Rectifies AC current to DC with a series of diodes

(NOTE: The alternator produces higher output at low engine speed and requires less maintenance than the generator.)

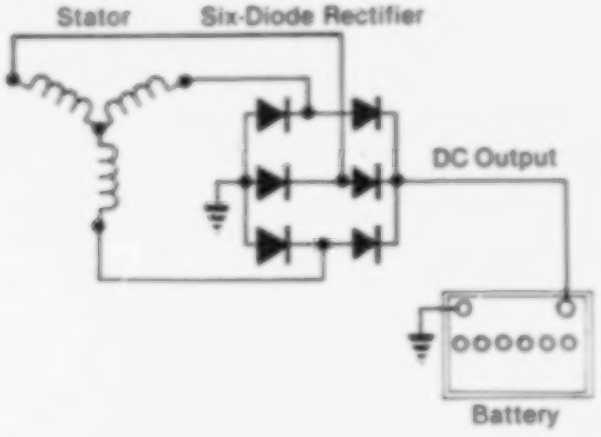
INFORMATION SHEET

XXXIX. Types of stator windings (Figures 21 and 22)

A. Wye-connected

(NOTE: The three coils are connected at one end to form a common point. The common point is called the *stator neutral junction*.)

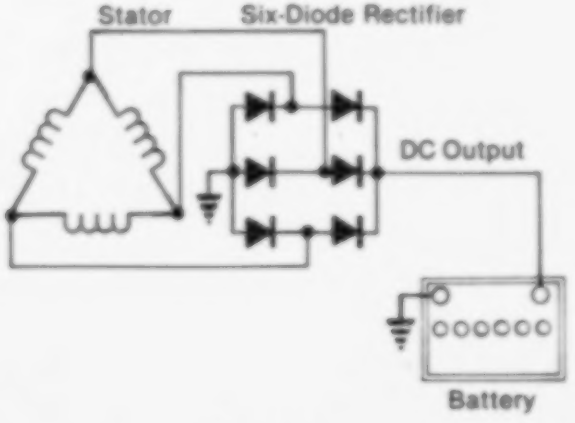
FIGURE 21



B. Delta-connected

(NOTE: The three coil windings are joined at their ends to form an electrical closed circuit with each terminal end connected to a positive and negative diode.)

FIGURE 22



INFORMATION SHEET

XL. Current and voltage regulation in an alternator

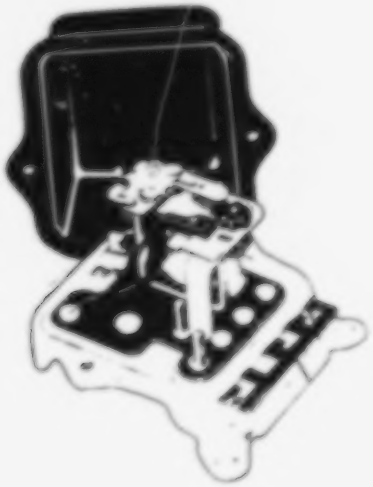
A. Current — Regulated by number of turns of wire in each phase

B. Voltage — Regulated by controlling current flow in rotor field

XLI. Types of voltage regulators for alternators (Figures 23 - 26)

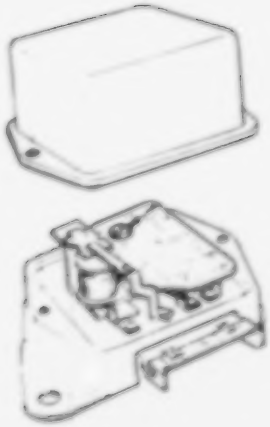
A. Electromechanical

FIGURE 23



B. Transistorized

FIGURE 24

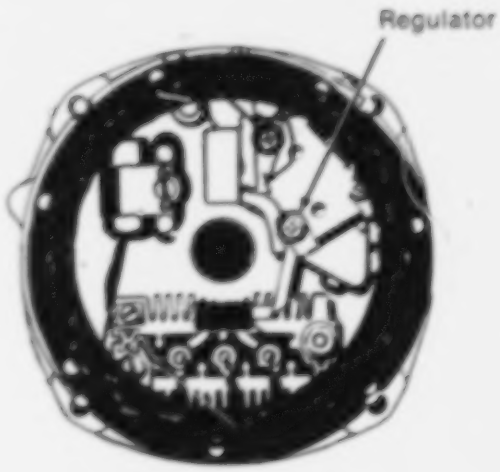


INFORMATION SHEET

C. Electronic or solid state

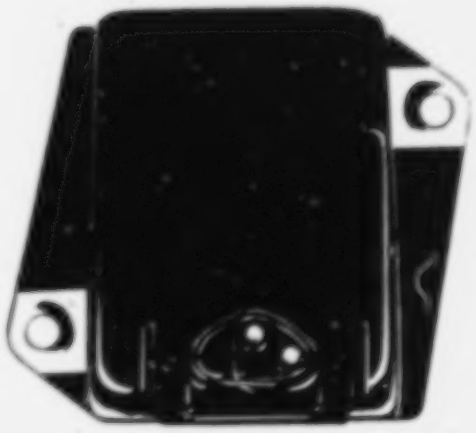
1. Internal

FIGURE 25



2. External

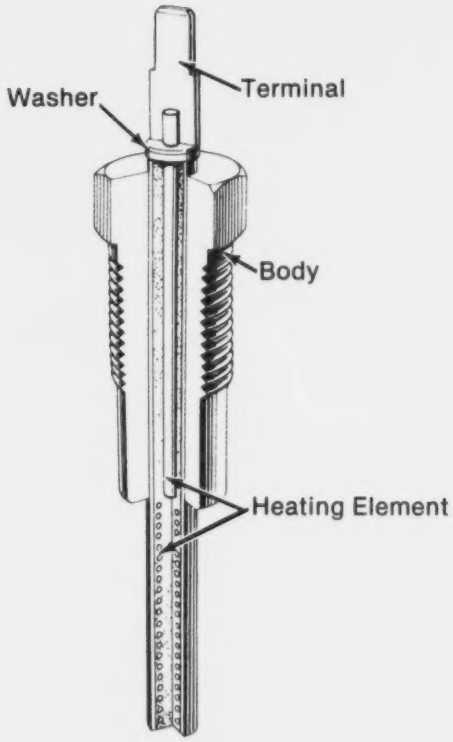
FIGURE 26



INFORMATION SHEET

XLII. Parts of a glow plug (Figure 27)

FIGURE 27



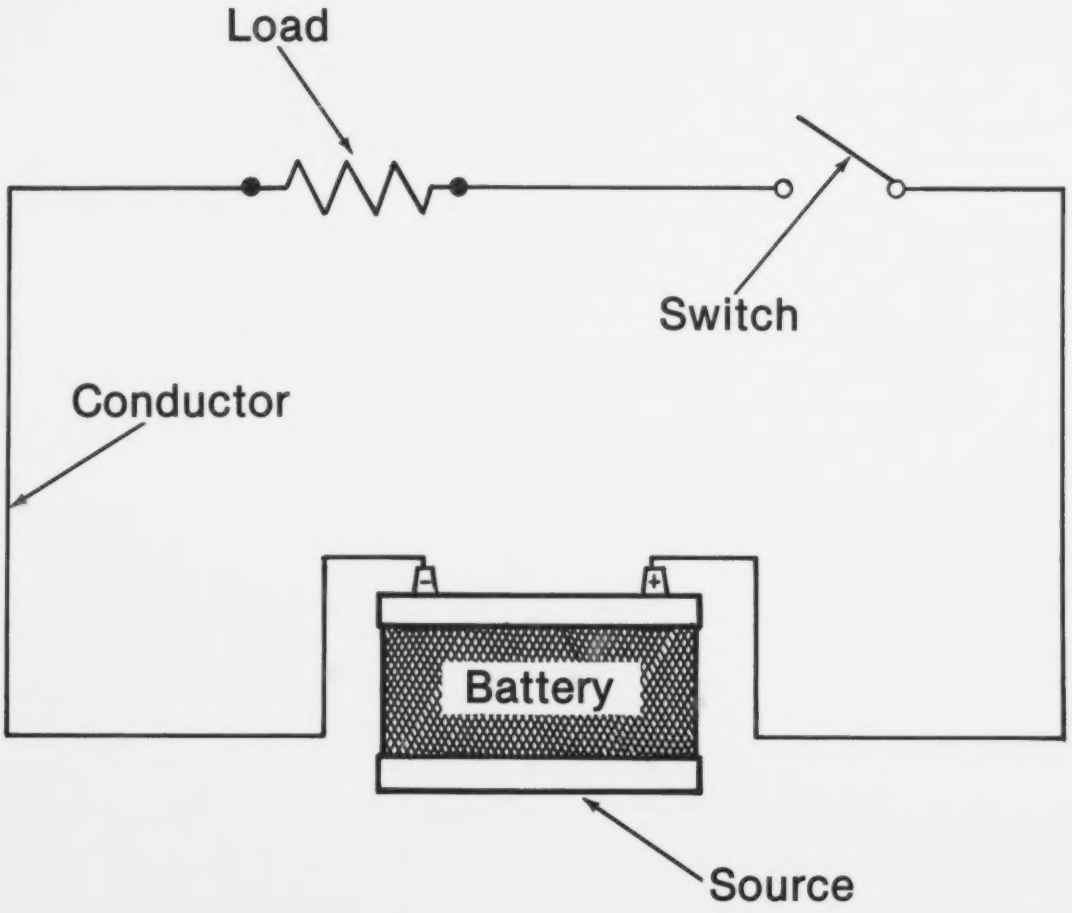
XLIII. Glow plug operation

(NOTE: Glow plugs are electrical preheating devices that aid in cold-weather starting on some diesel engines.)

A. Activating glow plug for correct length of time heats precombustion chambers to a temperature that is necessary for combustion when engine is turned on

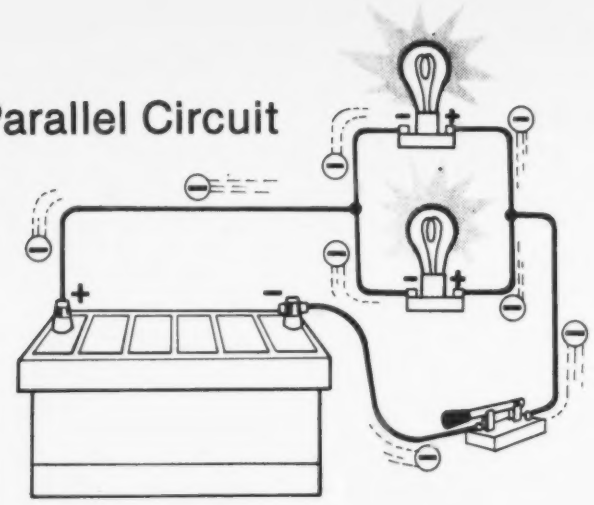
B. Glow plugs continue to heat precombustion chamber until engine is running smoothly

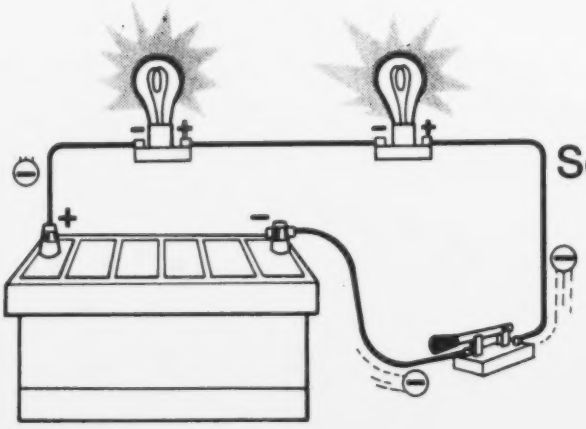
Basic Electrical Circuit



Types of Electrical Circuits

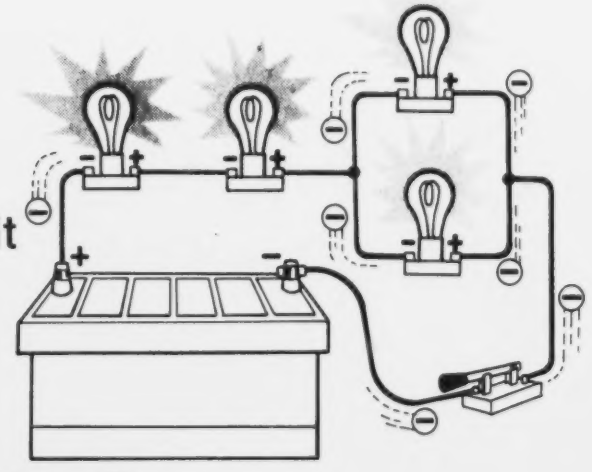
Parallel Circuit





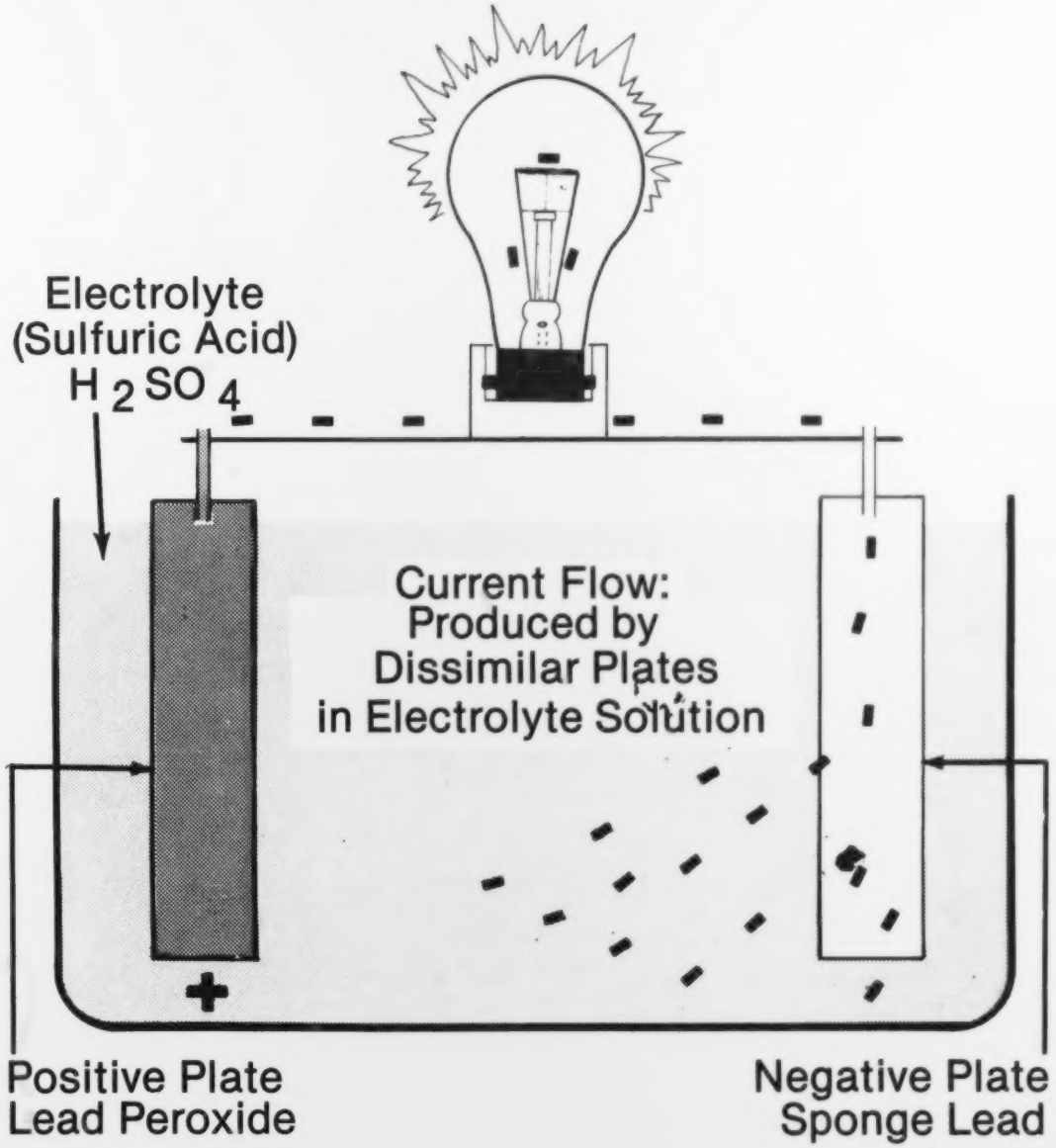
Series Circuit

Series-Parallel Circuit

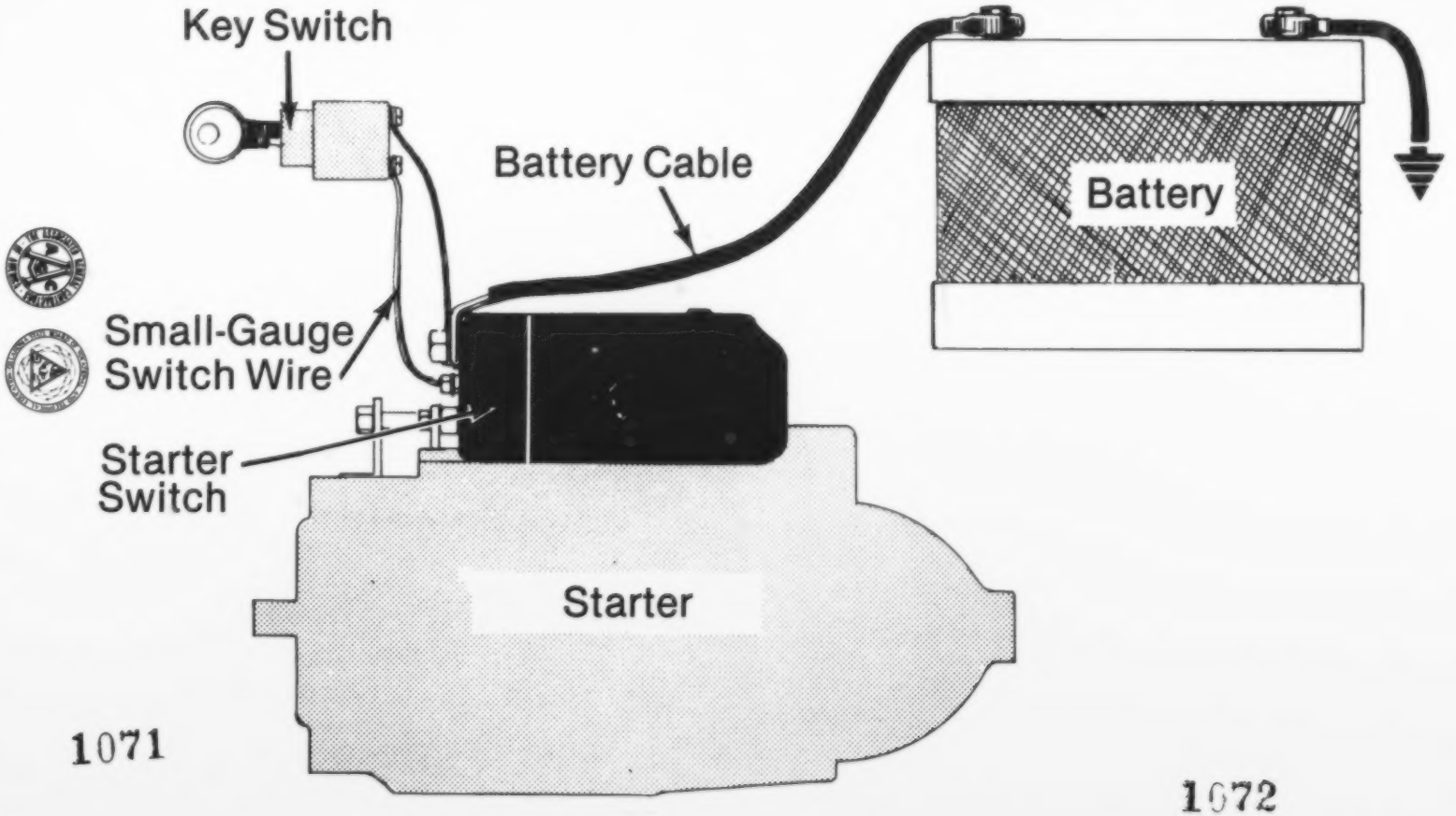


Current and Electrolyte

How a Battery Converts Chemical Energy into Electrical Energy



Components of the Starting System



1071

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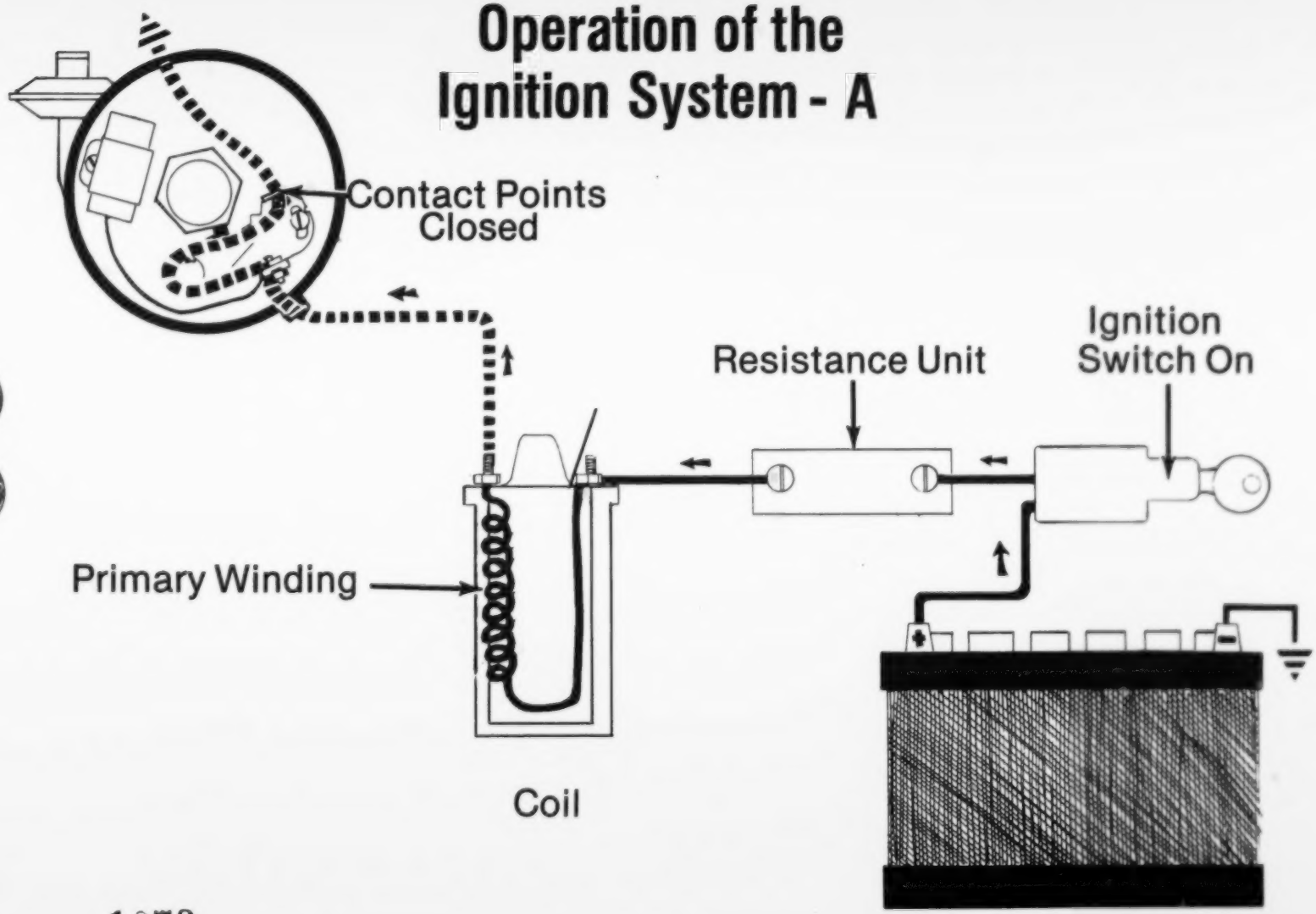
TM #4

HEM - 327-C

Operation of the Ignition System - A



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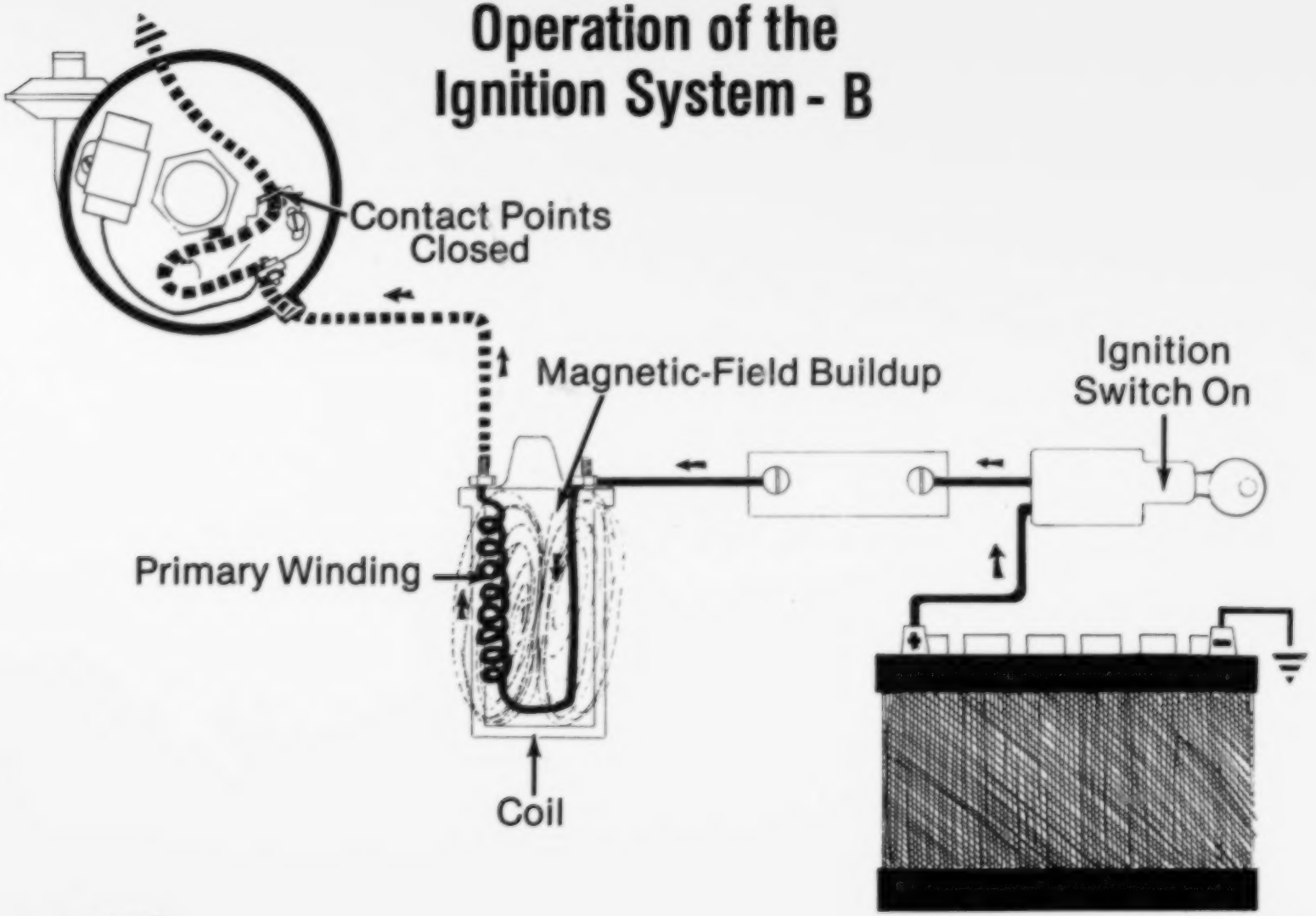
TM #5

HEM - 329-C

Operation of the Ignition System - B



TM #8

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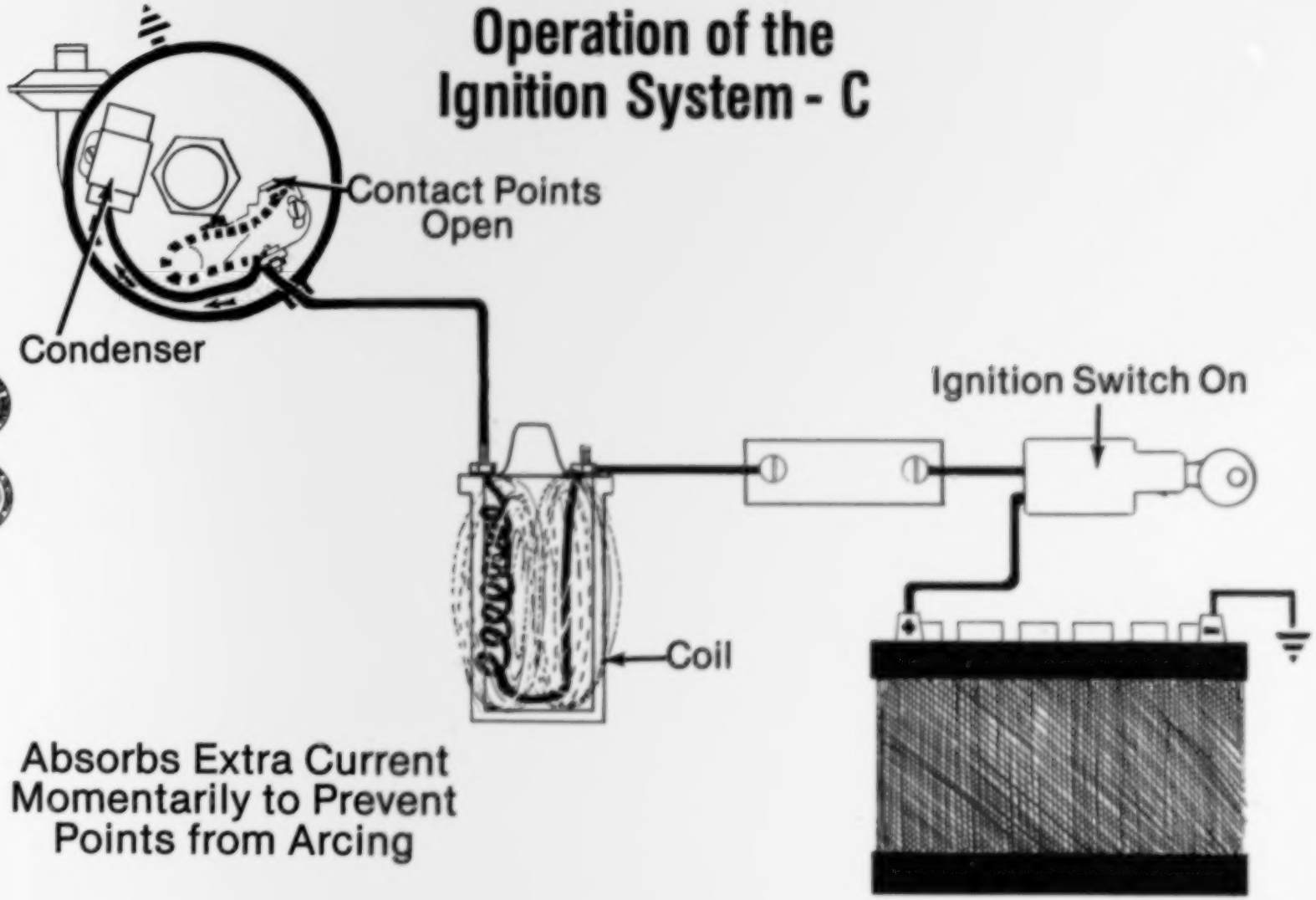
1076

HEM - 331-C

Operation of the Ignition System - C



Absorbs Extra Current Momentarily to Prevent Points from Arcing

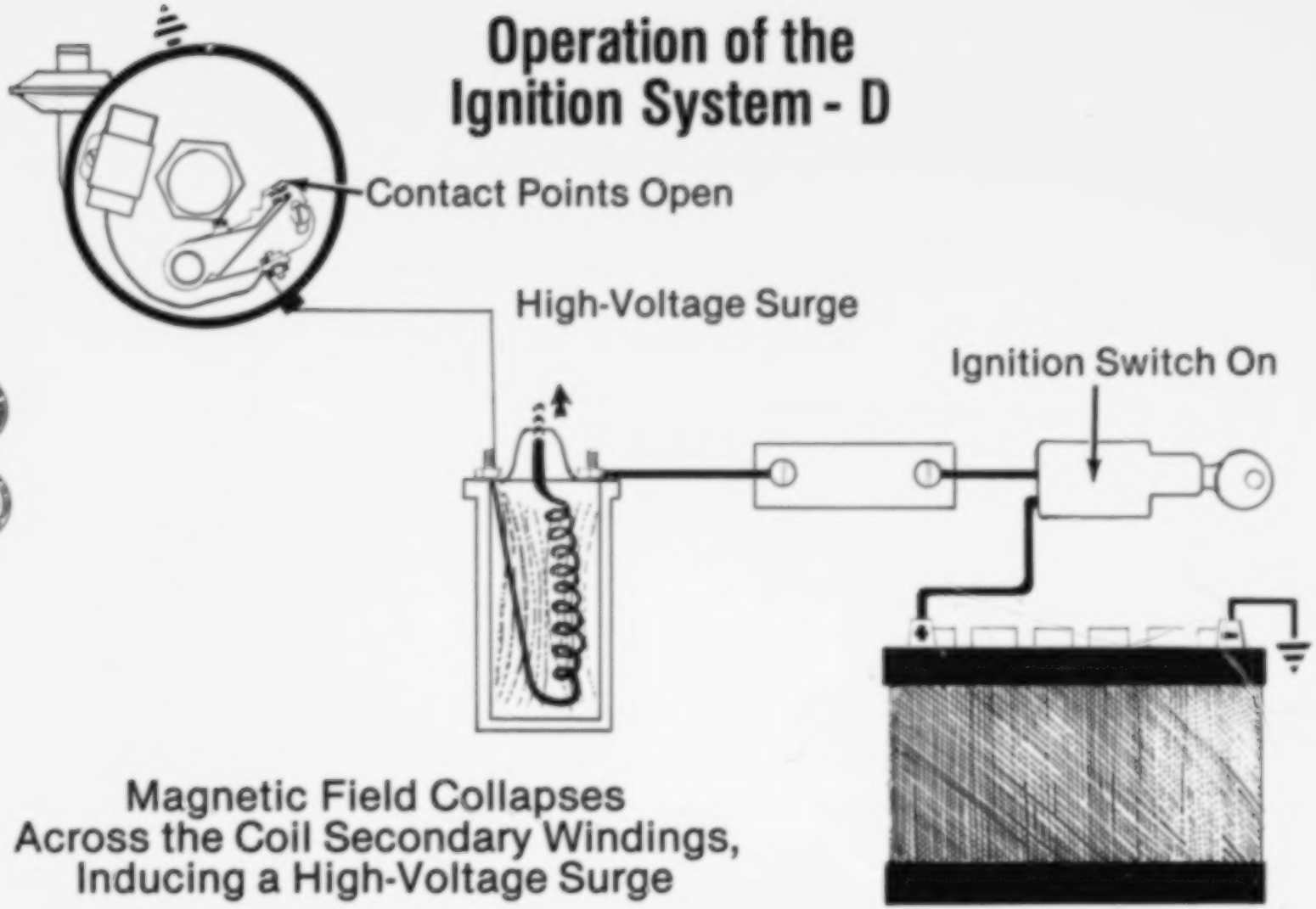
TM #7

1977

1078

HEM - 333-C

Operation of the Ignition System - D



Magnetic Field Collapses
Across the Coil Secondary Windings,
Inducing a High-Voltage Surge

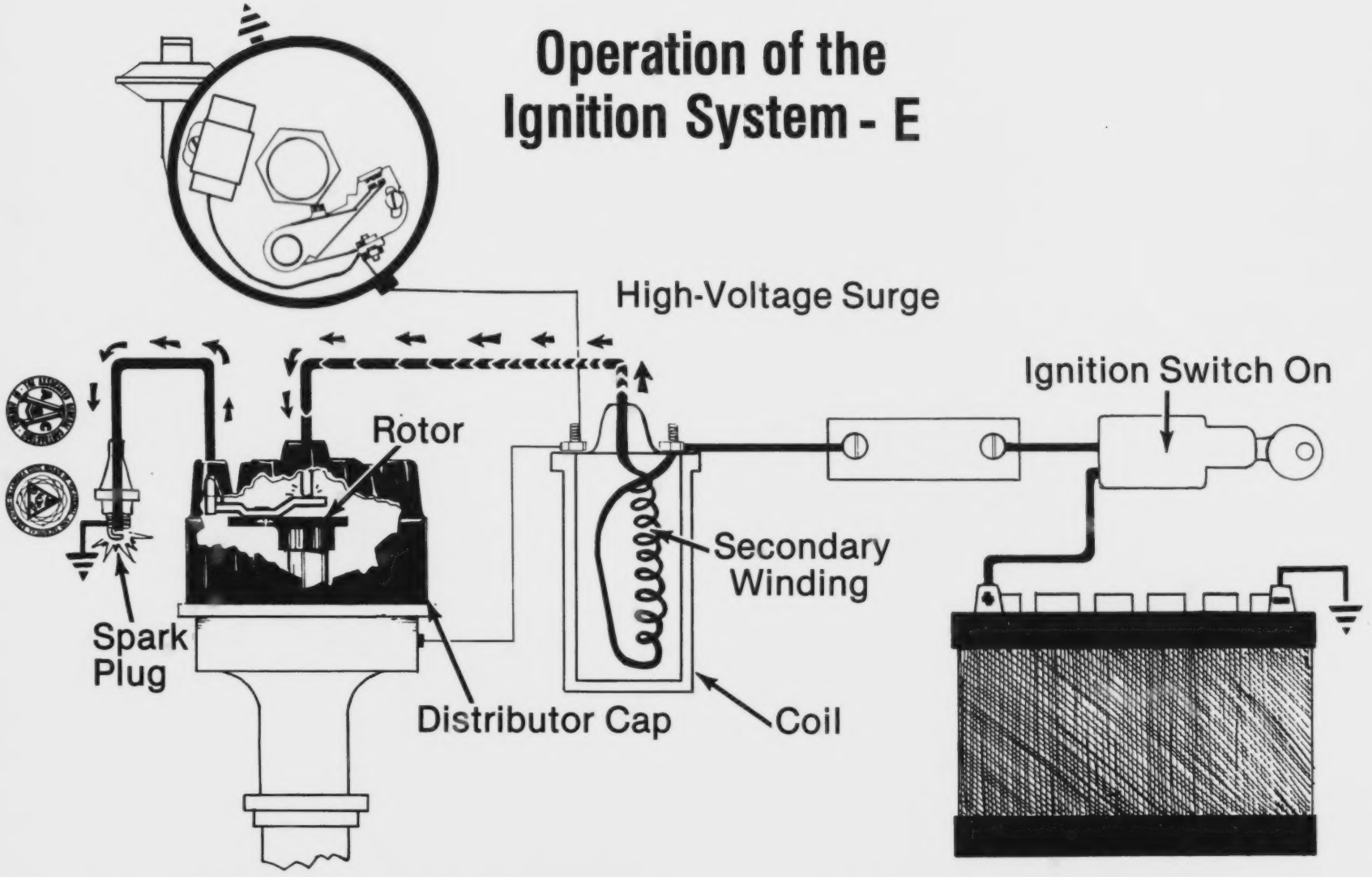
1079

1080

TM 68

HEM-336C

Operation of the Ignition System - E



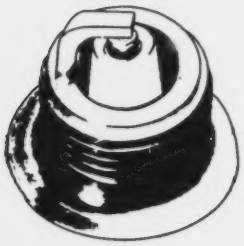
1081

1082

TM #9

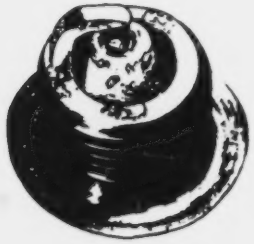
HEM - 337-C

Spark Plug Conditions

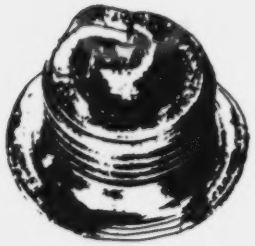


Normal

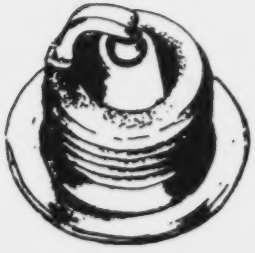
Preignition



Too Hot

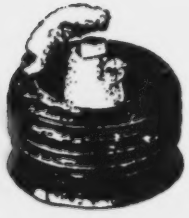


Oil Deposits



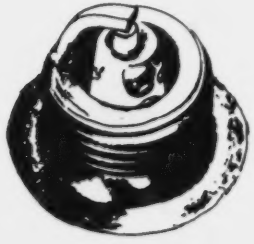
Carbon Deposits

1083



Modifier Deposits

High-Speed Glazing



Splashed Deposits

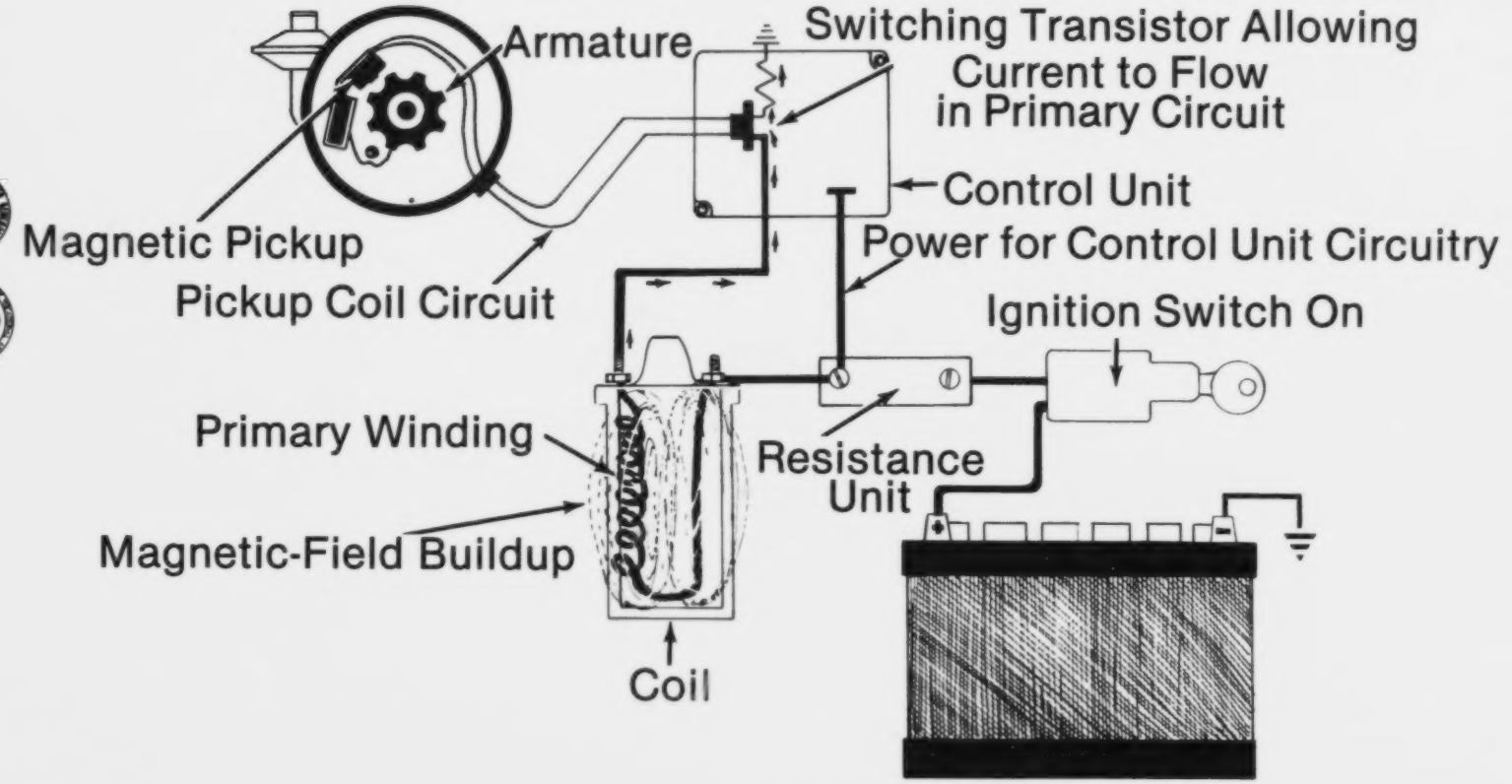
1084

TM #10

HEM - 339-C

Operation of Electronic Ignition System

Armature Teeth Not Aligned with Pickup Coil
No Current Flow in Pickup Circuit



TM #11

1085

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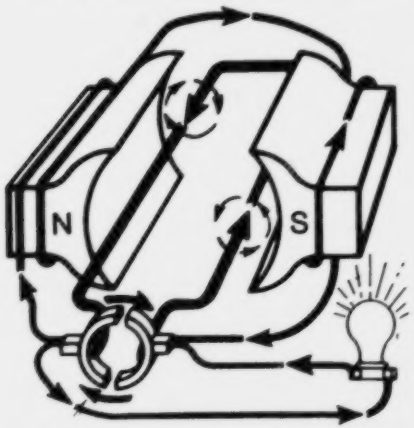
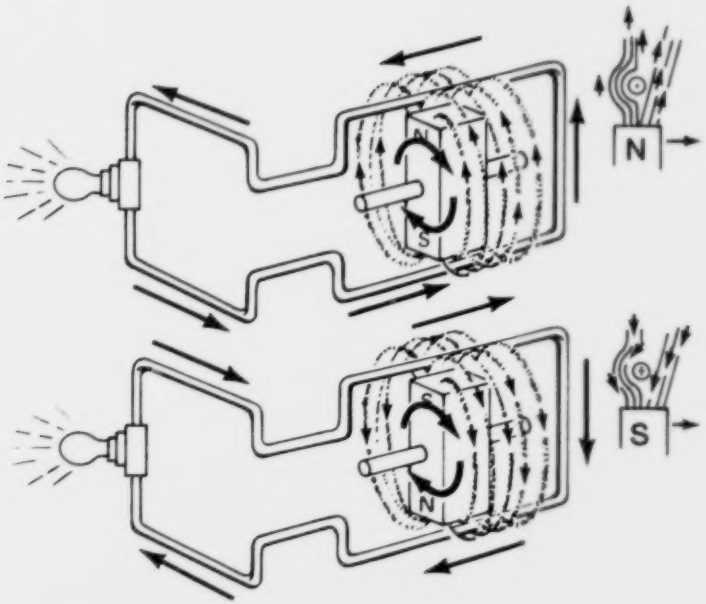
HEM - 341-C

Differences Between Generator and Alternator

Direction of Current



Generator



Alternator

TM #12

1087

1088

HEM - 343-C

ELECTRICAL SYSTEMS
UNIT V

JOB SHEET #1 — CONSTRUCT A SERIES CIRCUIT

I. Equipment and materials

A. 12-volt battery

B. Voltmeter

C. 2 single-lead light sockets

D. 2 bulbs to fit the light sockets

E. Single-pole toggle switch

F. Assortment of jumper leads

G. Circuit board or mounting board

II. Procedure

A. Attach two light sockets to circuit board

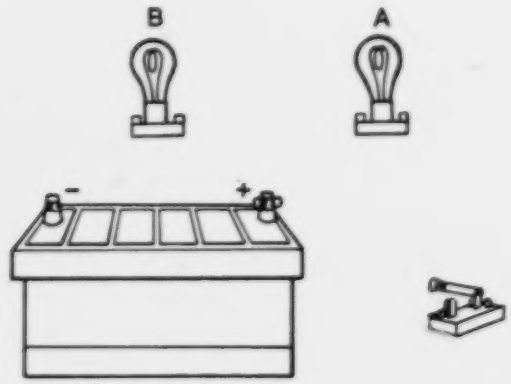
B. Install bulbs into light sockets

C. Attach switch to circuit board

D. Position battery close to circuit board (Figure 28)

(CAUTION: Avoid any arcing around the battery. Avoid personal contact with battery acid.)

FIGURE 28



JOB SHEET #1

E. Place switch in OFF position

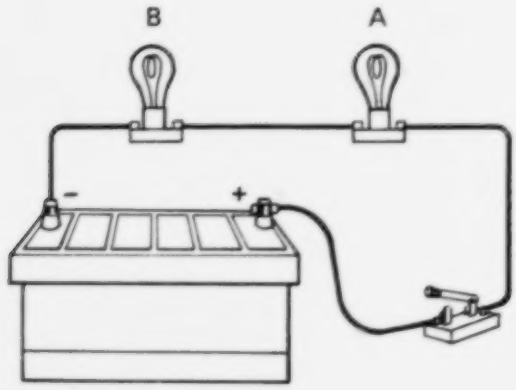
F. Connect a jumper lead between switch and wire from light socket A (See Figure 29)

G. Connect a jumper lead from base of light socket A to wire of socket B (See Figure 29)

H. Connect a jumper lead from base of socket B to negative post of battery (See Figure 29)

I. Connect a jumper lead from remaining terminal of switch to positive post of battery (Figure 29)

FIGURE 29



J. Move switch to ON or CLOSED position

(NOTE: Both bulbs will light, but at about one-half their normal intensity.)

K. Remove either bulb

(NOTE: The other bulb will go out.)

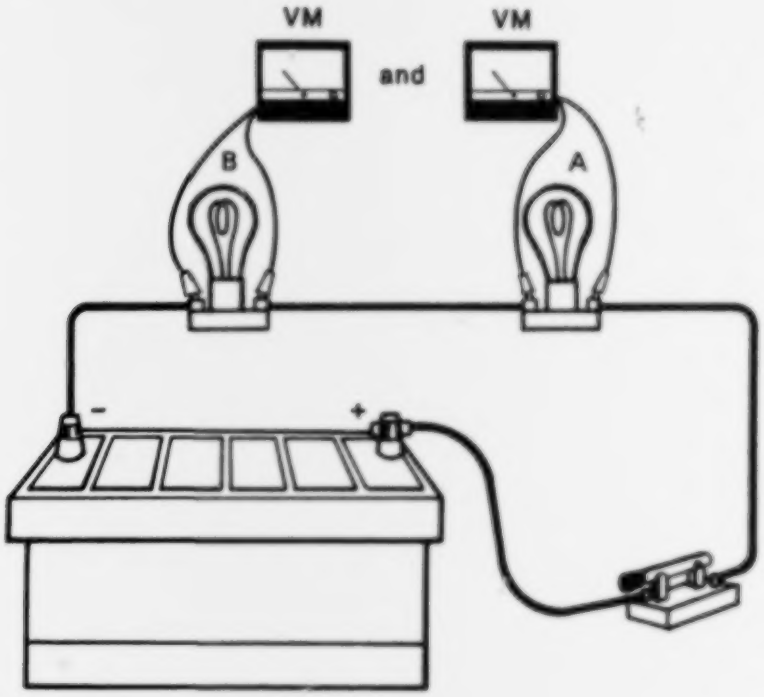
JOB SHEET #1

L. Reinstall removed bulb

M. Connect a voltmeter across light socket A connections and take voltage reading; repeat for light socket B (Figure 30)

(NOTE: The voltage-drop rating for each should be one-half the battery voltage.)

FIGURE 30



Principle: In a series circuit, the voltage will drop along the circuit. The total drop in a series circuit will always be equal to the applied voltage.

N. Clean work area; put away all equipment and materials

ELECTRICAL SYSTEMS
UNIT V

JOB SHEET #2 — CONSTRUCT A PARALLEL CIRCUIT

I. Equipment and materials

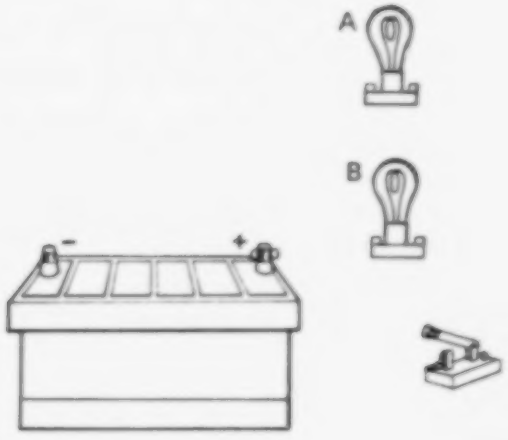
- A. 12-volt battery
- B. Voltmeter
- C. 2 single-lead light sockets
- D. 2 bulbs to fit light sockets, 12-volt
- E. Single-pole toggle switch
- F. Assortment of jumper leads
- G. Circuit board or mounting board

II. Procedure

- A. Attach two light sockets to circuit board
- B. Install bulbs into light sockets
- C. Attach switch to circuit board
- D. Position battery close to circuit board (Figure 31)

(CAUTION: Avoid arcing around the battery. Avoid personal contact with battery acid.)

FIGURE 31



JOB SHEET #2

E. Place switch in OFF position

F. Connect jumper lead (J1) between leads on bulbs A and B (Figure 32)

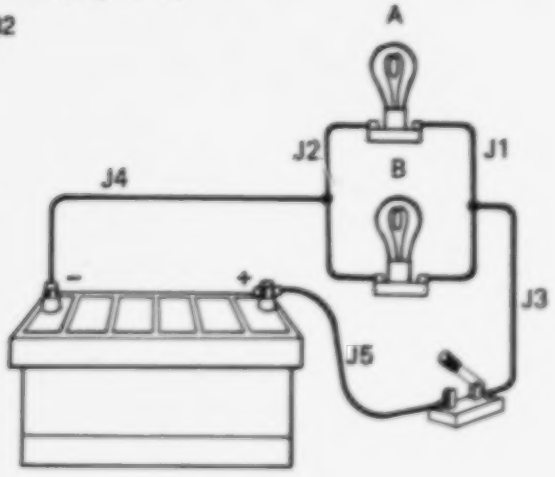
G. Connect jumper lead (J2) between bases of sockets A and B (See Figure 32)

H. Connect a jumper lead (J3) from switch terminal to jumper lead J1 (See Figure 32)

I. Connect a jumper lead (J4) between jumper lead J2 and battery negative terminal (See Figure 32)

J. Connect a jumper lead (J5) to switch terminal, and then to battery positive terminal (Figure 32)

FIGURE 32



K. Move switch to ON or CLOSED position

(NOTE: Both bulbs will light at normal intensity.)

L. Remove either bulb

(NOTE: The remaining bulb will light at its normal intensity.)

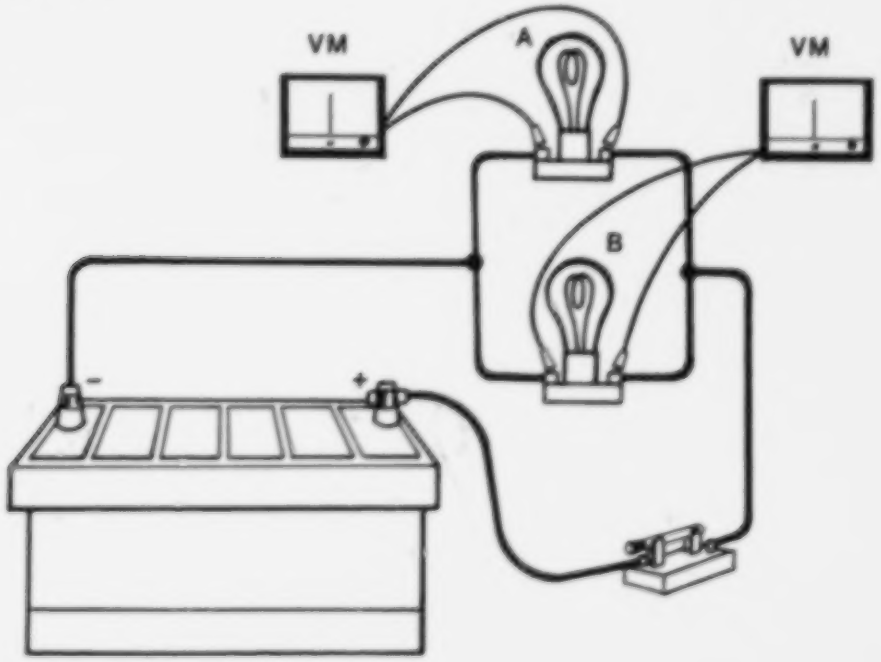
M. Reinstall removed bulb

JOB SHEET #2

N. Connect a voltmeter across connections of light socket A and take voltage reading; repeat for light socket B (Figure 33)

(NOTE: The readings should be the same as the battery voltage.)

FIGURE 33



Principle: The voltage will be the same at all points along a parallel circuit.

O. Clean work area; put away all equipment and materials

ELECTRICAL SYSTEMS
UNIT V

JOB SHEET #3 — CLEAN AND SERVICE A BATTERY

I. Equipment and materials

A. Vehicle

B. Full face shield

C. Rubber gloves

D. Protective clothing

E. Bristle brush

F. Wire brush (battery terminal brush)

G. Screwdriver

H. Battery clamp puller

I. Combination wrenches, 7/16 inch to 9/16 inch

J. Baking soda and water solution (2 tablespoons of baking soda to 1 pint of water)

K. Battery anticorrosion paste

L. Shop towels

JOB SHEET #3

II. Procedure

A. Put on face shield and rubber gloves

B. Disconnect battery cables from battery posts

(NOTE: Always disconnect the grounded battery cable first to avoid short circuits. Use care to avoid twisting the battery cable post.)

1. Pry clamp open (Figures 34 and 35)

FIGURE 34

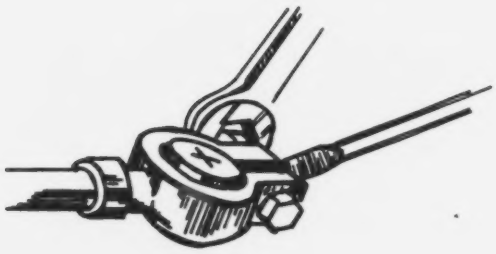
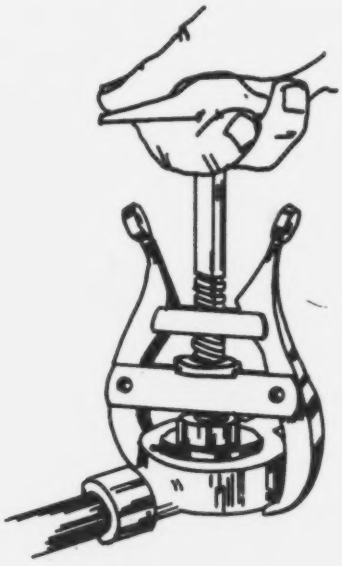


FIGURE 35

2. Use battery clamp puller to remove cable clamp (Figure 36)

FIGURE 36

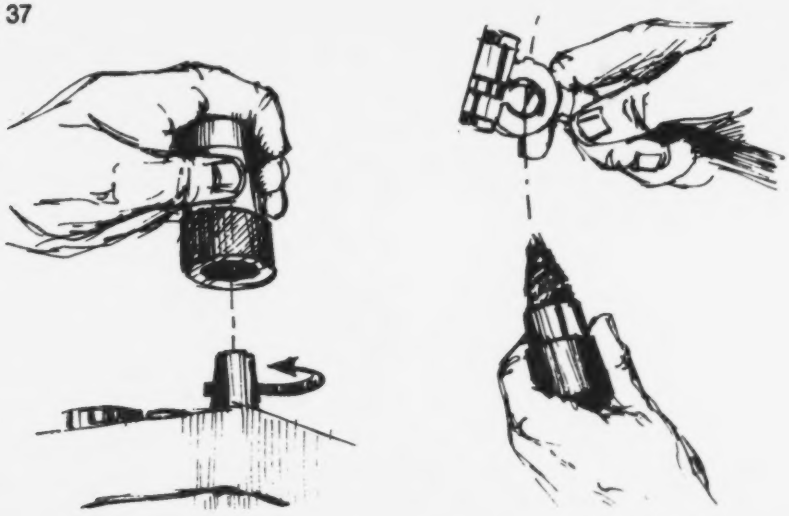


JOB SHEET #3

C. Clean battery cable clamp and battery post (Figure 37)

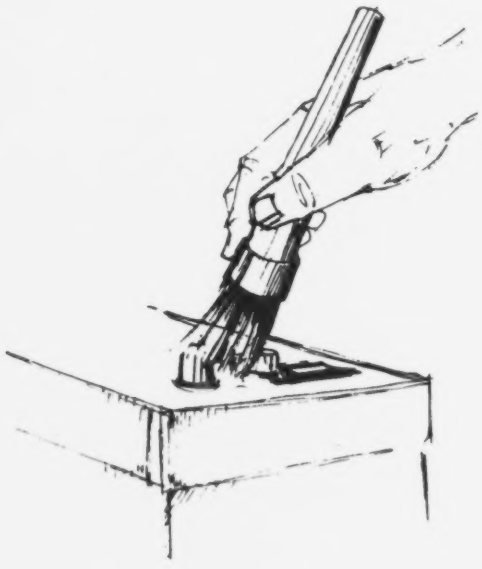
(NOTE: Battery posts and inside of battery cable clamps must be clean and bright.)

FIGURE 37



D. Remove loose dirt and corrosion particles from top of battery (Figure 38)

FIGURE 38

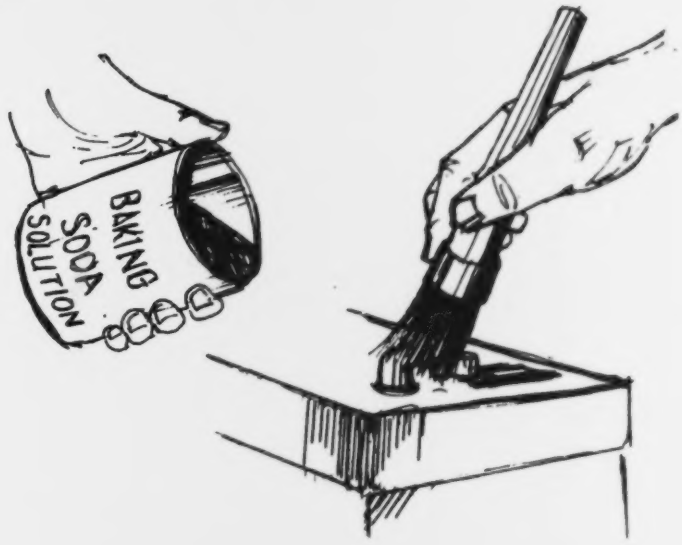


JOB SHEET #3

E. Brush soda-water solution on battery, battery posts, clamps, and battery hold-down (Figure 39)

(NOTE: Keep water and soda from entering the battery through the vent holes in the vent caps.)

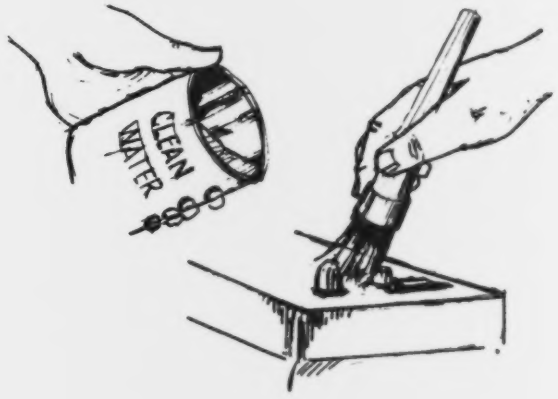
FIGURE 39



F. Wash away residue with clean water (Figure 40)

(NOTE: Remove all residue that may have lodged around battery, frame, or parts of the vehicle.)

FIGURE 40



JOB SHEET #3

G. Dry battery and battery cables with a clean cloth

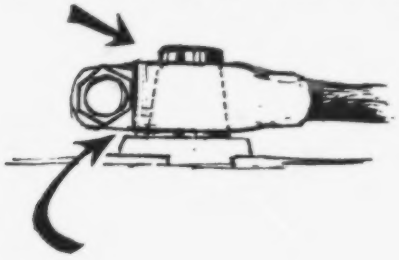
(CAUTION: Do not paint or get paint on battery as it will short out the battery.)

H. Reconnect battery cables to battery posts (Figure 41)

(CAUTION: Always reconnect the power cable first and the ground cable last.)

FIGURE 41

Battery Post Slightly Above Clamp



I. Spread a coating of battery anticorrosion paste over cable clamps and terminals

J. Remove vent caps

K. Check electrolyte level in all cells

L. Add water if necessary to bring electrolyte up to proper level

(NOTE: Do not overfill.)

M. Clean work area; clean and put away all tools and equipment

ELECTRICAL SYSTEMS
UNIT V

JOB SHEET #4 — REMOVE AND REPLACE A BATTERY

f. Equipment and materials

A. Vehicle

B. Full face shield

C. Protective clothing

D. Wire brush

E. Screwdriver

F. Battery clamp puller

G. Combination wrenches, 7/16 inch to 9/16 inch

H. Battery cable spreader

I. Battery post and cable cleaner

J. Battery lift strap

K. Battery anticorrosion paste

L. Baking soda and water solution

M. Shop towels

JOB SHEET #4

II. Procedure

(NOTE: Observe the location of the positive post so that the battery can be reinstalled in the same way.)

A. Put on face shield

B. Disconnect battery cables from battery posts

(NOTE: Always disconnect the grounded battery cable first to avoid short circuits. Use care to avoid twisting the battery cable post.)

1. Pry clamp open (Figures 42 and 43)

FIGURE 42

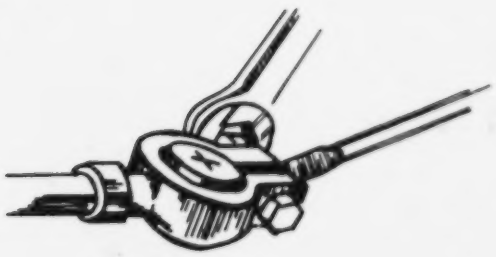
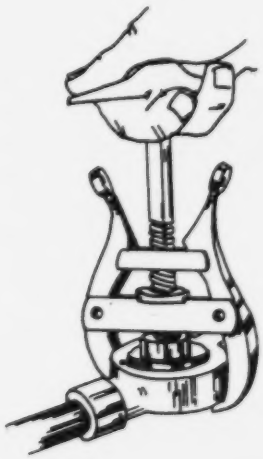


FIGURE 43

2. Use battery clamp puller to remove cable clamp (Figure 44)

FIGURE 44



JOB SHEET #4

C. Remove battery hold-down

D. Remove battery from carrier

(NOTE: Use a suitable battery lift strap to lift the battery.)

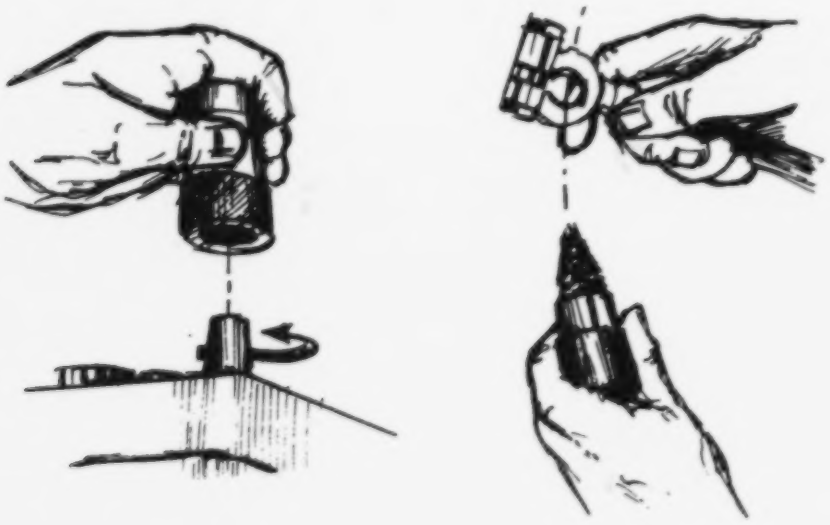
E. Inspect battery carrier for dirt or corrosion

(NOTE: Clean with baking soda and water solution as required.)

F. Check battery cables for worn or frayed insulation

G. Clean inside of battery cable clamps and battery posts until bright (Figure 45)

FIGURE 45



JOB SHEET #4

H. Set battery into place using a lift strap

(NOTE: Position the battery to allow for correct battery cable attachment.)

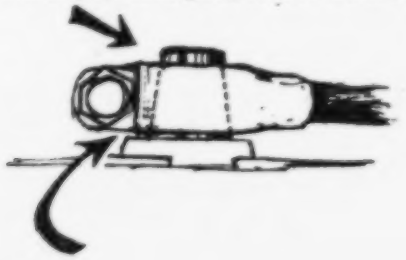
I. Install battery hold-down clamp or strap and tighten securely

J. Reconnect battery cables to battery posts (Figure 46)

(NOTE: Always reconnect the power cable first and the ground cable last.)

FIGURE 46

Battery Post Slightly Above Clamp



K. Tighten battery cable clamps securely

(NOTE: Use care to avoid twisting the battery cable post.)

L. Spread a coating of battery anticorrosion paste over cable clamps and terminals

M. Clean work area; put away all tools and equipment

ELECTRICAL SYSTEMS
UNIT V

JOB SHEET #5 — MEASURE BATTERY ELECTROLYTE WITH A HYDROMETER

I. Equipment and materials

- A. Battery
- B. Hydrometer
- C. Shop towels
- D. Water container

II. Procedure

- A. Remove vent caps from battery
- B. Insert hydrometer tube into first cell
- C. Squeeze rubber bulb to draw electrolyte into hydrometer to suspend float

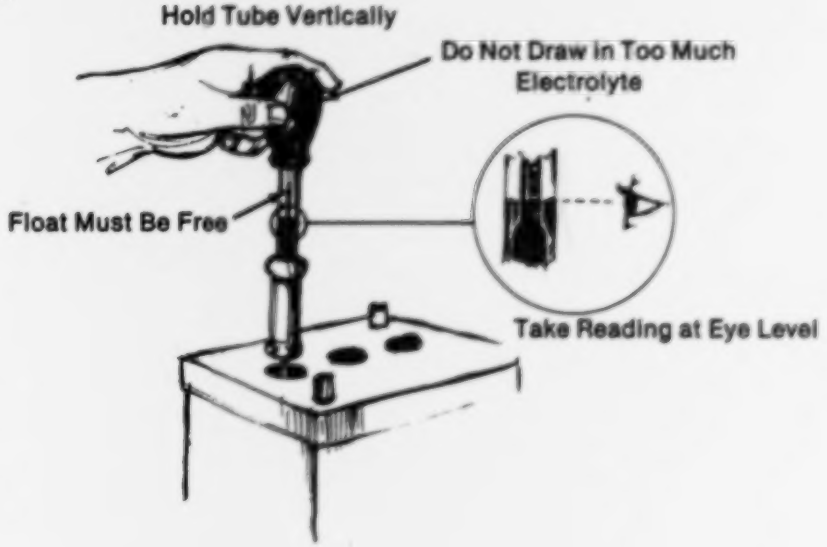
  (NOTE: If the electrolyte level is too low, add water until electrolyte level is correct; charge for one hour, and recheck.)

JOB SHEET #5

D. Take reading at eye level (Figure 47)

(NOTE: Make sure the float is not bumping the top of hydrometer tube or sticking to the side of the tube. Write down reading for each cell.)

FIGURE 47



E. Replace tube in cell, then squeeze bulb to return electrolyte to cell

F. Repeat for other cells

JOB SHEET #5

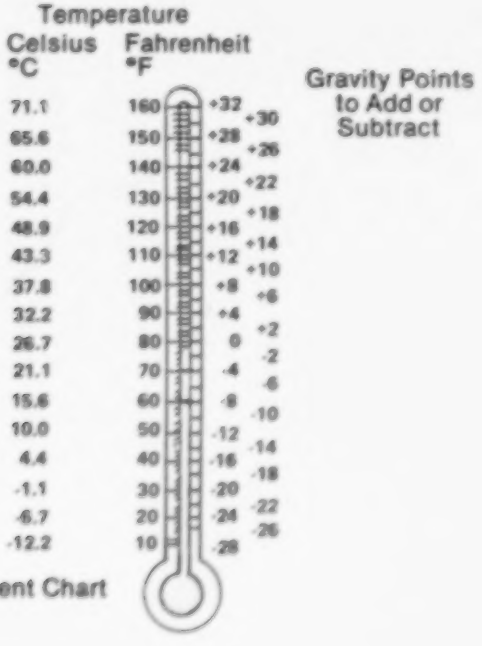
G. Adjust the readings for temperature (Figure 48)

1. Add four gravity points (0.004) to the reading for each 10° F (5.5°C) above 80°F (26.7°C)

2. Subtract four gravity points (0.004) for each 10°F (5.5°C) below 80°F (26.7°C)

(NOTE: Specific gravity should read from 1.215 to 1.270, corrected for 80°F [26.7°C] electrolyte temperature. The variation in readings between cells should be no more than 0.050. If the readings are not within this range, further testing will be required.)

FIGURE 48



Temperature-Adjustment Chart

H. Replace vent caps upon completion of test

I. Flush any spilled electrolyte with clean water

J. Clean work area; clean and put away all tools and equipment

ELECTRICAL SYSTEMS
UNIT V

JOB SHEET #6 — LOAD TEST A BATTERY

I. Equipment and materials

A. Battery

B. Battery capacity tester

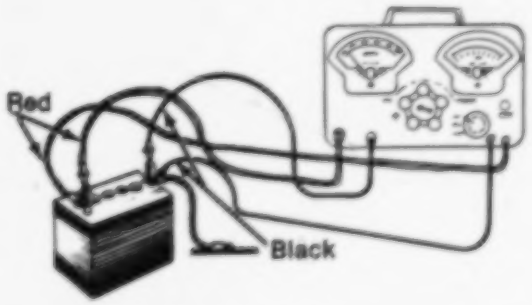
C. Appropriate conductors

D. Appropriate service manual

II. Procedure

A. Connect tester (Figure 49)

FIGURE 49



B. Tighten rheostat knob to apply a load to battery

(CAUTION: Do not apply the load to the battery for more than fifteen seconds at a time.)

C. Apply load equal to three times ampere/hour rating of battery being tested

(NOTE: Ampere/hour rating may be marked on the outside of the battery case. If not; consult manufacturer's specifications for the vehicle's requirements.)

D. Read battery voltage at end of fifteen seconds

(NOTE: If voltage drops below 9.6 volts in fifteen seconds, proceed to the three-minute charge test. See Job Sheet #7.)

E. Loosen rheostat to relieve load at end of fifteen seconds

F. Disconnect tester

G. Clean work area; clean and put away all tools and equipment

ELECTRICAL SYSTEMS
UNIT V

JOB SHEET #7 — CHARGE TEST A BATTERY FOR THREE MINUTES

I. Tools and equipment

A. Battery

B. Adjustable, fast-rate battery charger

C. Battery capacity tester

D. Appropriate conductors

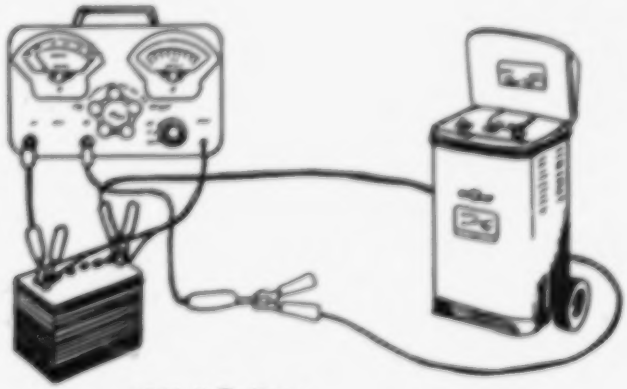
E. 12-volt battery

II. Procedure

(NOTE: Charge test cannot be performed on service-free batteries because the individual cells cannot be checked.)

A. Connect tester and charger (Figure 50)

FIGURE 50



12-Volt Battery

B. Turn charger on and adjust the charging rate to 40 amperes

C. Charge battery for three minutes

D. Read individual cell voltages with battery still in operation

(NOTE: If cell voltages vary by more than 0.1 volt, replace the battery.)

JOB SHEET #7

E. Read total battery voltage

(NOTE: If total battery voltage is over 15.5 volts, the battery is unsatisfactory and must be given a long, slow charge and load tested again. If voltage under load test is less than 9.6 volts, replace battery.)

F. Clean work area; clean and put away all tools and equipment

ELECTRICAL SYSTEMS
UNIT V

JOB SHEET #8 — START AN ENGINE USING A NEGATIVE-GROUND BOOSTER BATTERY

I. Equipment and materials

A. Two vehicles

B. Battery booster cables

C. Shop towels

D. Face shield

E. Rubber gloves

F. Wire brush

G. Negative-ground booster-battery system

II. Procedure

(CAUTION: When connecting a booster battery, use care to avoid hurting yourself or damaging engine's electrical system.)

(NOTE: This procedure is Ford's recommendation for using a jumper between two vehicles [for a negative-ground battery].)

A. Put on face shield and rubber gloves

B. Use wire brush to clean connectors on battery

C. Remove vent caps from both batteries

D. Cover vent holes with shop cloths to prevent splashing of electrolyte

E. Do not allow two vehicles to touch each other (if applicable)

F. Be sure all electrical equipment is turned off on engine to be started

G. Connect end of one cable to positive (+) terminal of booster battery

H. Connect other end of cable to positive (+) terminal of dead battery

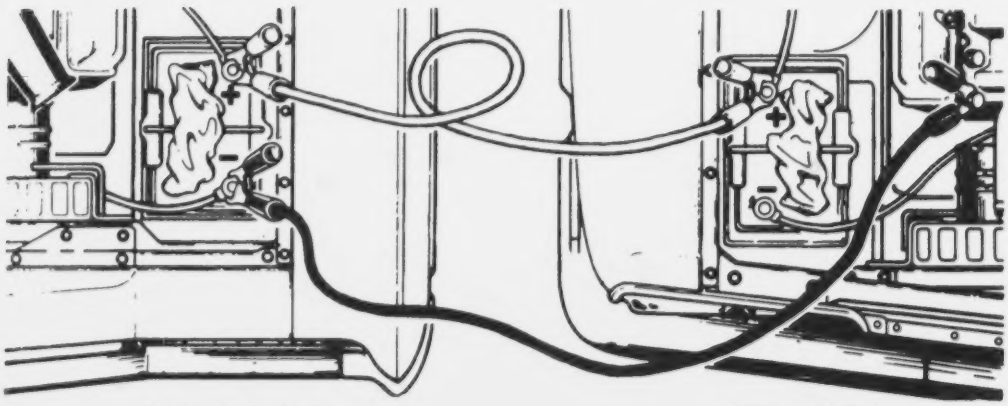
I. Connect one end of second cable to negative (–) terminal of booster battery

JOB SHEET #8

J. Connect other end of second cable to engine block of engine you are trying to start (Figure 51)

(CAUTION: To prevent arcing around battery and a possible explosion, do not connect second cable to negative [grounded] terminal of engine you are trying to start.)

FIGURE 51



Charged Battery Dead Battery

Used with permission of the Gregg Division, McGraw-Hill Book Company.

K. Start engine that has booster battery

(NOTE: After starting, let engine run for a few minutes to help restore power to battery.)

L. Start engine that has low battery

(CAUTION: Never operate starting motor for more than thirty seconds at a time. Pause for a few minutes to allow motor to cool off, and then try it again.)

M. Disconnect cable from engine block after vehicle has started

N. Disconnect other end of cable from engine with booster battery

O. Disconnect second cable from engine with low battery

P. Disconnect other end of second cable from engine that has booster battery

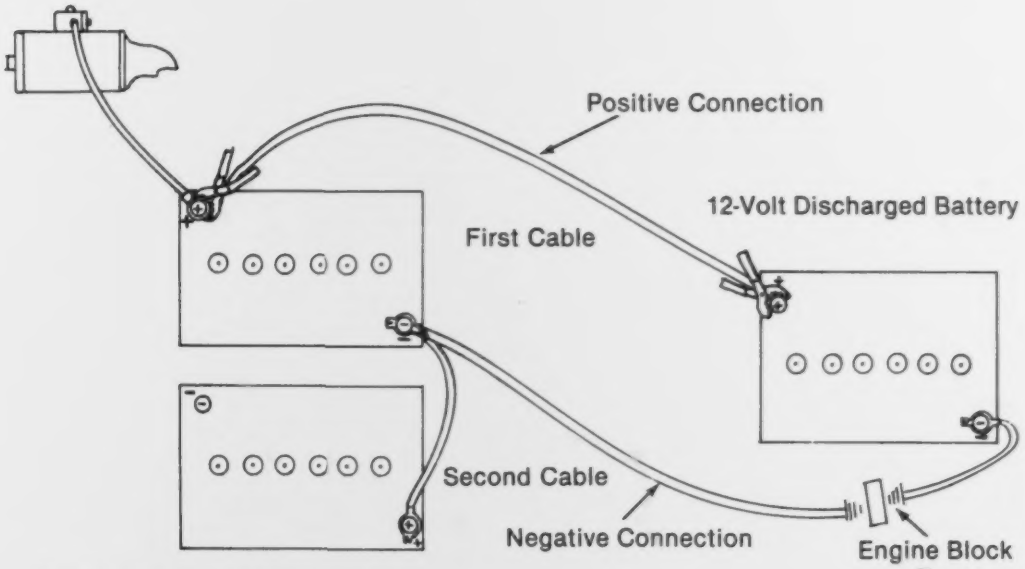
Q. Clean work area; put away all tools and equipment

ELECTRICAL SYSTEMS
UNIT V

JOB SHEET #9 — USE A 24-VOLT BATTERY-BOOSTER SYSTEM TO START A VEHICLE WITH A 12-VOLT SYSTEM

(NOTE: This type of ground system [either positive (+) or negative (−)]can be boosted if both battery polarities are the same; see Figure 52)

FIGURE 52



Two-Battery 24-Volt Booster System

(CAUTION: DO NOT use a single 24-volt battery to boost a 12-volt battery.)

I. Equipment and materials

A. Two vehicles

B. Battery booster cables

C. Face shield

D. Two-battery, 24-volt booster system

E. 12-volt discharged battery

JOB SHEET #9

F. Shop cloths

G. Rubber gloves

II. Procedure

(CAUTION: When connecting booster battery, use care to avoid hurting yourself or damaging the electrical equipment.)

A. Position vehicles closely enough to each other for booster cables to easily reach batteries

(NOTE: Do not allow the two vehicles to touch each other. If the electrical systems in the two vehicles are not compatible, connecting them by allowing the vehicles to touch could cause serious damage.)

B. Make sure that all electrical equipment except ignition is turned off on vehicle you are trying to start

C. Put on face shield and rubber gloves

D. Remove vent caps from both batteries

(NOTE: Cover the battery vent holes with shop cloths to prevent splashing of electrolyte.)

E. Connect end of one cable to positive (+) terminal of booster battery

F. Connect other end of cable to positive (+) terminal of discharged battery

(CAUTION: Never stand over battery when connecting cables.)

G. Connect one end of second cable to negative (–) terminal of booster battery

H. Connect other end of second cable to engine block or frame of vehicle you are trying to start

(CAUTION: Do not connect second cable to vehicle battery; this could cause a spark that could ignite any hydrogen in the battery and produce a serious explosion.)

I. Start vehicle that has booster battery

J. Start vehicle that has discharged battery

(CAUTION: Never operate starting motor for more than thirty seconds at a time. Pause for a few minutes to allow motor to cool off; then try again.)

JOB SHEET #9

K. Disconnect booster cables after disabled vehicle has started

1. Disconnect negative cable from engine block or frame
2. Disconnect other end of negative cable from booster battery
3. Disconnect other cable from positive terminals

L. Clean work area; clean and put away all tools and equipment

ELECTRICAL SYSTEMS
UNIT V

JOB SHEET #10 — LOAD TEST A STARTER

I. Equipment and materials

A. Vehicle

B. Battery-starter tester

C. Battery hydrometer

D. Basic hand-tool set

E. Safety glasses

F. Appropriate service manual

II. Procedure

(NOTE: The engine should be at normal operating temperature to obtain an accurate test.)

A. Put on safety glasses

B. Open engine compartment (where applicable)

C. Remove cover from battery compartment

D. Disconnect ignition-coil secondary load from distributor cap; ground the lead.

E. Test battery specific gravity

(NOTE: The battery must have at least three-fourths charge before you proceed with the starter load test.)

F. Turn variable-resistor control knob on tester to OFF position

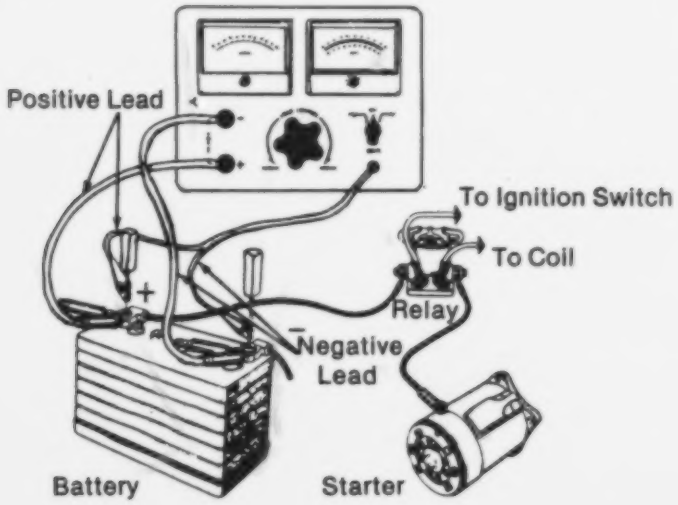
G. Connect tester ammeter leads to battery

H. Set voltmeter selector to 16-volt scale

JOB SHEET #10

III. Connect voltmeter leads to battery (Figure 53)

FIGURE 53



J. Connect a remote starter switch according to manufacturer's instructions

K. Crank engine long enough to read cranking voltage; record readings

(CAUTION: Do not crank the engine longer than fifteen seconds at a time without allowing the starter to cool.)

L. Turn variable-resistor control knob on tester until voltmeter reads the cranking voltage previously recorded; read the equivalent of starter current draw or load on ammeter

(CAUTION: Do not leave the variable-resistor control knob on longer than fifteen seconds.)

M. Confer with instructor on test results

N. Clean work area; clean and put away all tools and equipment

ELECTRICAL SYSTEMS
UNIT V

JOB SHEET #11 — TEST STARTER-CIRCUIT RESISTANCE

I. Equipment and materials

A. Vehicle

B. Voltmeter

C. Basic hand tools

D. Safety glasses

E. Appropriate service manual

II. Procedure

(NOTE: In order to check the voltage drop or resistance in a circuit, current must be flowing in the circuit. Therefore, all of the following test readings will be taken while the engine is cranking. High resistance in the supply-circuit wiring or connections will cause the starter to crank the engine at a slower-than-normal rate.)

(CAUTION: Do not crank the engine longer than fifteen seconds at one time without allowing the starter to cool.)

A. Open engine compartment (where applicable)

B. Remove cover from battery compartment

C. Disconnect coil lead from distributor cap and connect to a good ground, or remove distributor primary lead on high-energy ignition systems

(NOTE: Removal of distributor primary lead prevents the engine from starting during test procedures.)

D. Set voltmeter to read on lowest scale

E. Test starting-system insulated circuit

(NOTE: The following connections are for a negative-ground system; reverse leads for a positive-ground system.)

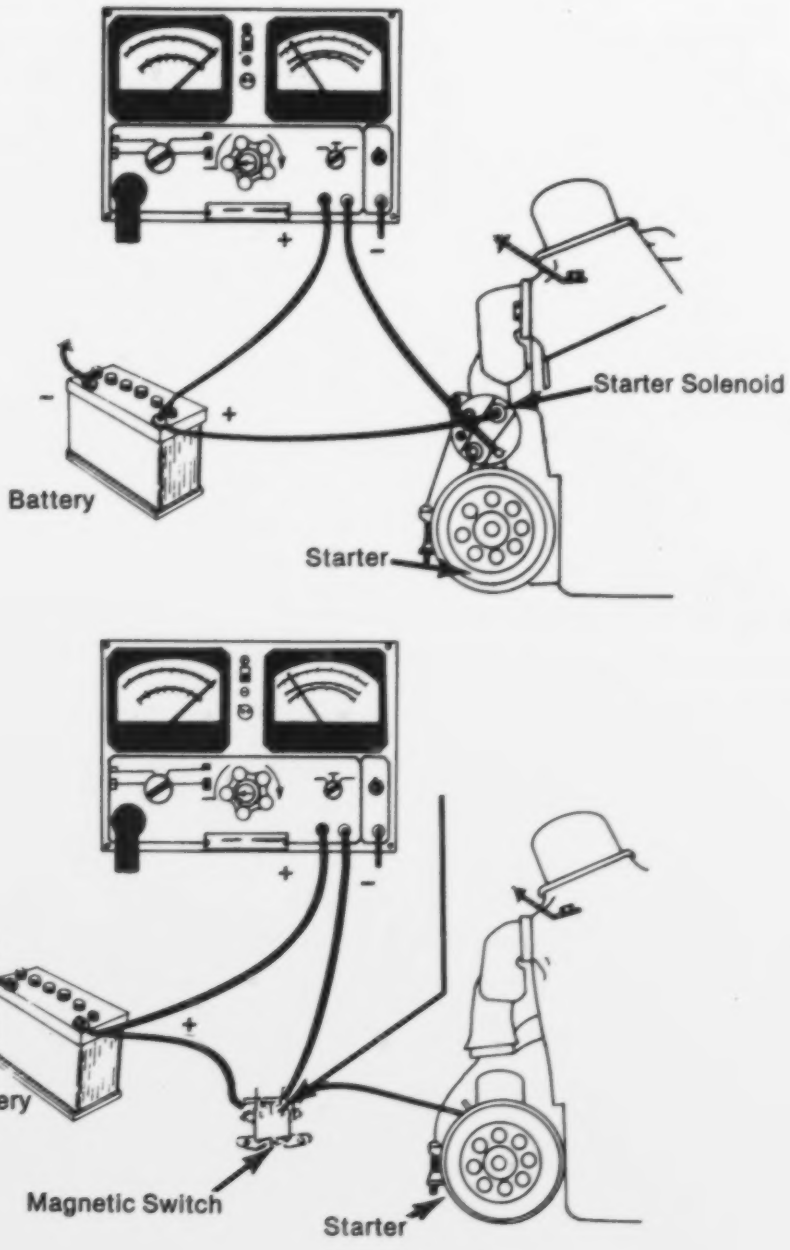
1. Connect voltmeter positive test lead to battery positive post (See Figure 54)

JOB SHEET #11

2. Connect voltmeter negative test lead to starter terminal (Figure 54)

(NOTE: Select the system similar to the one on which you are working.)

FIGURE 54



JOB SHEET #11

3. Crank engine and observe voltmeter readings while cranking

(NOTE: The readings should be within the manufacturer's specifications or those in Table 1.)

TABLE 1

Maximum Allowable Voltage Drop in the Insulated Starter Circuit

	6-Volt System	12-Volt System
Each cable	0.1	0.2
Each connection	0.0	0.0
Each switch	0.1	0.1
Starter solenoid switch	0.3	0.3
Total circuit voltage drop	0.4	0.5

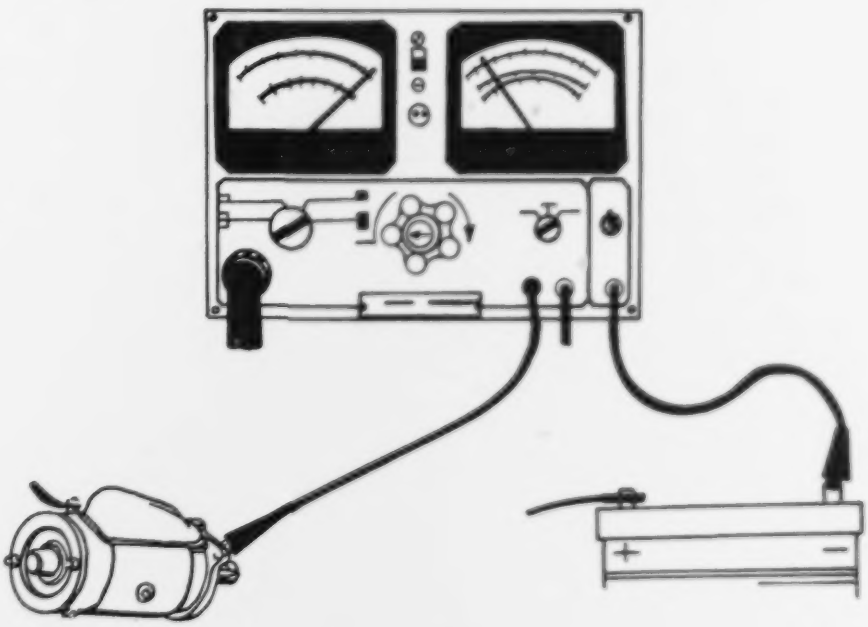
F. Test starting system ground-circuit resistance

1. Connect voltmeter positive lead to starter frame (See Figure 55)

(NOTE: Scrape the starter frame where the connection is made to ensure a good connection.)

2. Connect voltmeter negative lead to battery negative post (Figure 55)

FIGURE 55



3. Crank engine and observe voltmeter reading while cranking

   (NOTE: The readings should be within manufacturer's specifications or those in Table 2.)

TABLE 2

Maximum Allowable Voltage Drop in the Starter Ground Circuit

Total ground-circuit voltage drop	6-Volt System	12-Volt System
	0.1 volt	0.2 volt

G. Confer with your instructor on test results

H. Clean work area; clean and put away all tools and equipment

ELECTRICAL SYSTEMS
UNIT V

JOB SHEET #12 — TEST STARTER CONTROL-CIRCUIT RESISTANCE

I. Equipment and materials

A. Vehicle

B. Voltmeter

C. Basic hand-tool set

D. Seat cover

E. Safety glasses

II. Procedure

(NOTE: Consult manufacturer's wiring diagram to identify the components in the control circuit, such as the ignition switch, neutral-start switch, starter relay, magnetic switch, or solenoid windings. These components are connected in series so that any one component with high resistance will affect the total control circuit.)

A. Open and remove cover from engine compartment

B. Protect driver's seat with seat cover

C. Set voltmeter to read on lower scale

D. Disconnect coil lead from distributor cap and connect to a good ground, or remove distributor primary lead on high-energy ignition systems

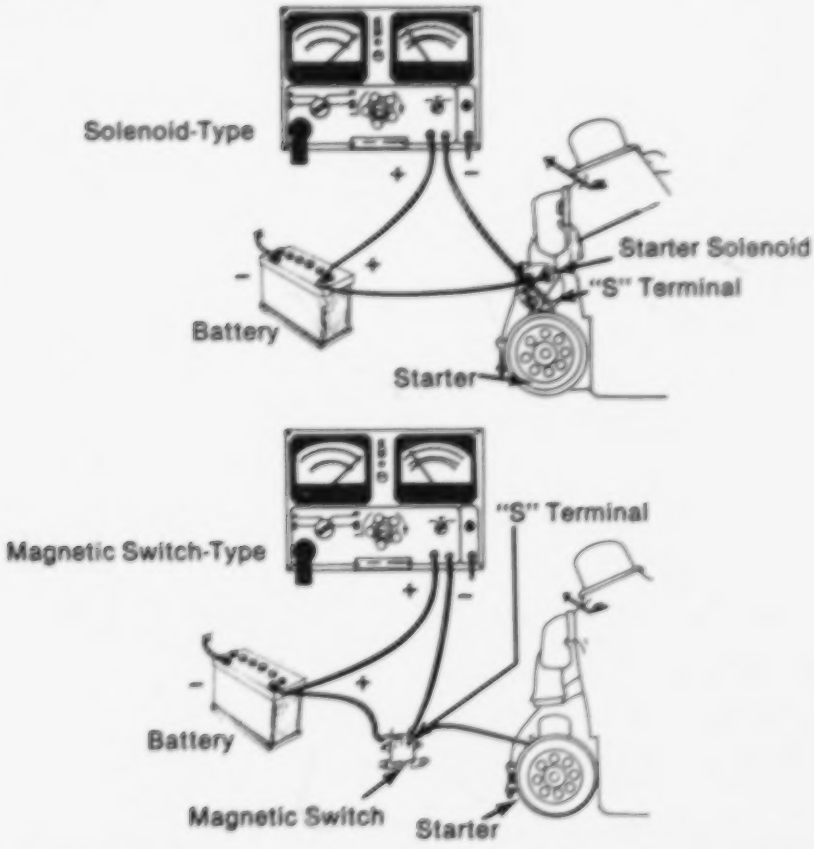
E. Test complete control-circuit resistance

(NOTE: The following connections are for a negative-ground system; reverse leads for a positive-ground system.)

1. Connect positive voltmeter lead to battery positive post (See Figure 58)

2. Connect voltmeter negative lead to "S" terminal on solenoid or magnetic switch (Figure 56)

FIGURE 56



3. Crank engine using control switch (usually the ignition switch) while taking voltage-drop reading

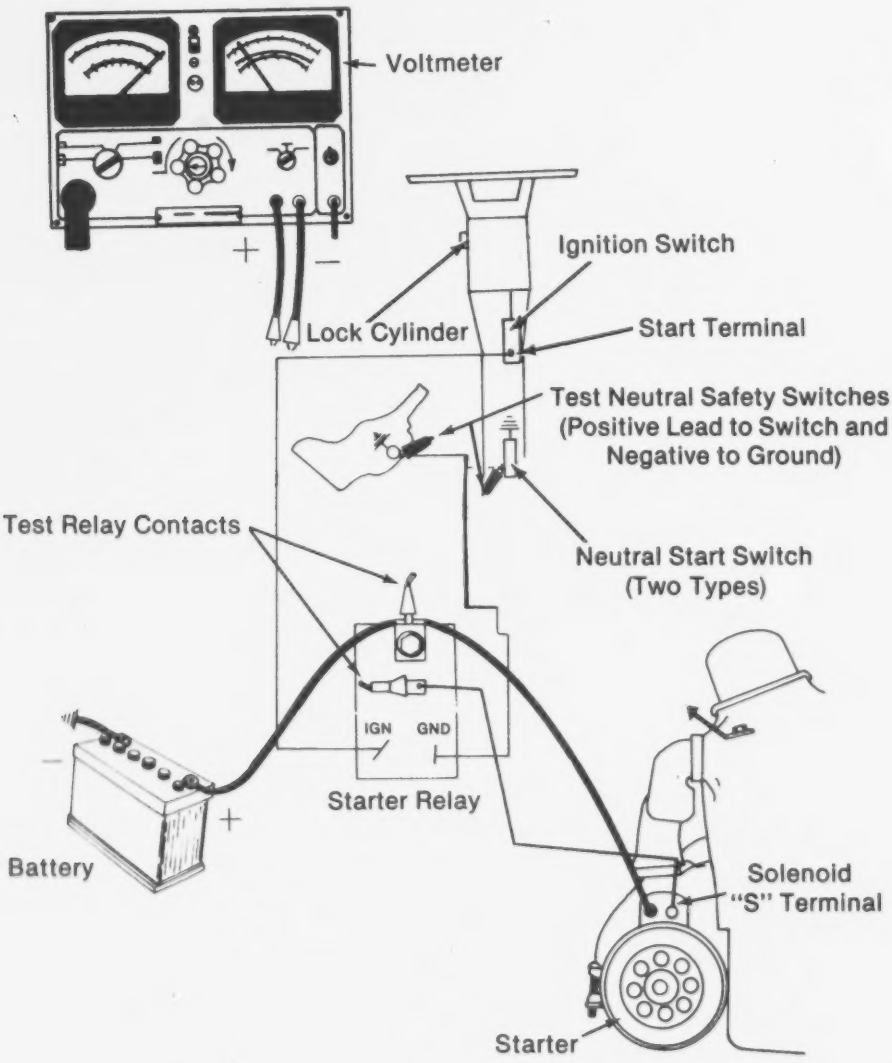
(NOTE: A voltage drop of less than 0.5 volts indicates that the circuit is in good condition. A voltage drop of greater than 0.5 volts indicates excessive resistance. However, on certain vehicles, a slightly higher voltage drop could be normal.)

JOB SHEET #12

F. Isolate areas of high resistance by connecting voltmeter leads across each component of control circuit while observing polarity; check voltage-drop readings with starter control switch operated (Figure 57)

(NOTE: A reading of more than 0.1 volt across any one wire or switch is usually an indication of trouble.)

FIGURE 57



JOB SHEET #12

G. Confer with your instructor on test results

H. Clean work area; put away all tools and equipment

ELECTRICAL SYSTEMS
UNIT V

JOB SHEET #13 — REMOVE AND REPLACE A STARTER

I. Equipment and materials

A. Vehicle

B. Combination wrenches, 3/8 inch to 3/4 inch

C. 3/8-inch to 3/4-inch sockets with 3/8-inch drive

D. Ratchet with 3/8-inch drive

E. 3-inch and 6-inch extensions with 3/8-inch drive

F. Small ignition-wrench set

G. Battery cable pliers

H. Jack

I. Jack stands

J. Creeper

II. Procedure

A. Remove starter

1. Disconnect battery ground cable

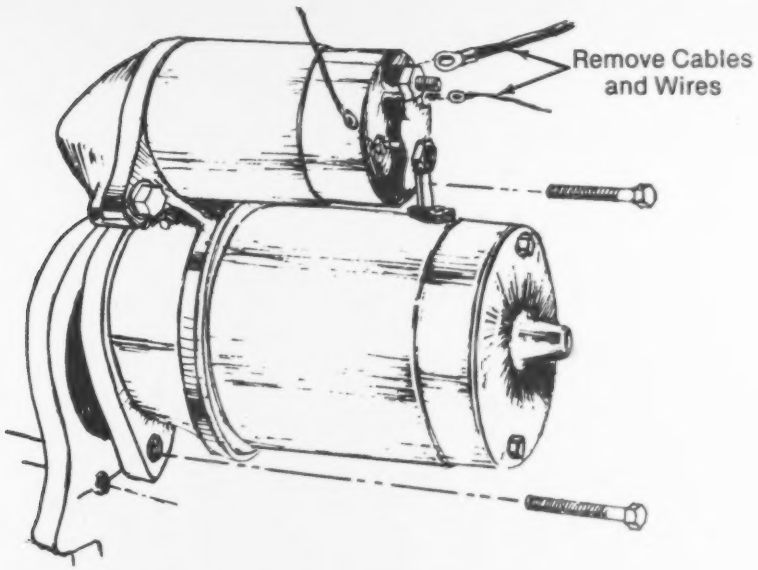
2. Suspend vehicle on jack stands (where applicable)

3. Remove cables and electrical wires from starter

(NOTE: In some cases, you must remove the starter retaining bolts and lower the starter in order to provide easy removal of the starter wires and cables.)

4. Remove starter retaining bolts as required (Figure 58)

FIGURE 58



5. Remove other starter brackets if used

6. Remove starter from engine

(CAUTION: Starters are heavy and should be handled carefully during removal to avoid damage to the starter or injury to the worker.)

B. Replace starter

1. Clean starter and block mounting surfaces

2. Position starter in mounting position and start retaining bolts

3. Tighten starter retaining bolts securely

4. Position starter wires and cables; start retaining nuts

5. Tighten starter wires and retaining nuts securely

(NOTE: Avoid overtightening and twisting off small retaining nuts.)

6. Replace any brackets that may have been removed; tighten brackets securely

JOB SHEET #13

7. Check all connections
8. Remove jack stands and lower vehicle to floor
9. Replace battery ground cable
10. Start engine two or three times to check starter action

C. Clean work area; clean and put away all tools and equipment

ELECTRICAL SYSTEMS
UNIT V

JOB SHEET #14 — DISASSEMBLE, CHECK, AND REASSEMBLE A STARTER

I. Equipment and materials

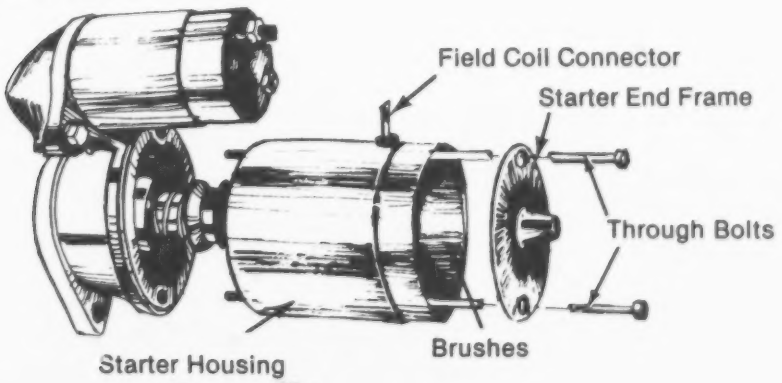
- A. Starter, removed from vehicle
- B. Combination wrenches, 3/8 inch to 3/4 inch
- C. Needle nose pliers
- D. 2 pliers
- E. Hammer
- F. Small wooden block
- G. Suitable armature growler and test light
- H. Battery
- I. Jumper cables

II. Procedure

- A. Disassemble starter
  1. Disconnect field coil connectors from solenoid
  2. Remove through bolts
  3. Remove starter end frame
  4. Remove starter housing by pulling it off over the front of armature
  5. Remove armature and drive assembly from drive housing (Figure 59)

     (NOTE: Sometimes the solenoid and shift-lever assembly must be removed before the drive assembly and armature can be removed.)

FIGURE 59



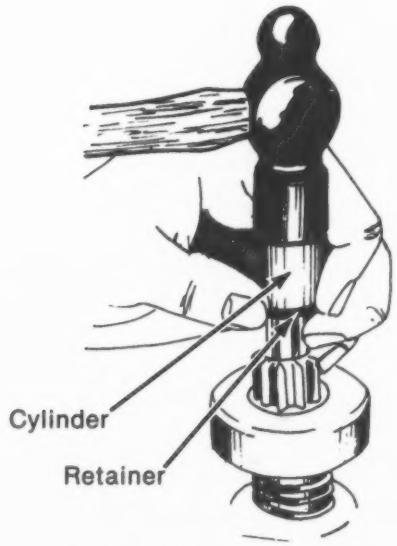
JOB SHEET #14

6. Remove starter drive from armature shaft

   a. Remove thrust washer

   b. Tap retainer toward armature to free the snap ring (Figure 60)

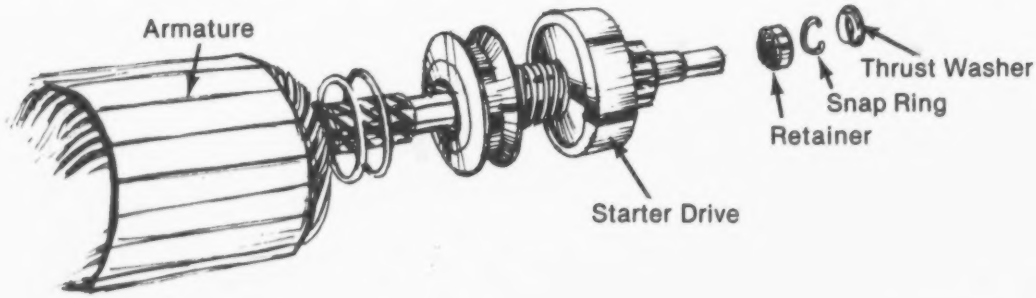
FIGURE 60



   c. Remove snap ring and retainer

   d. Remove starter drive and assist spring (Figure 61)

FIGURE 61



7. Remove starter brushes if required

JOB SHEET #14

B. Check condition of starter

1. Clean all starter components

   (NOTE: Clean all parts by wiping with clean cloths. The armature, field coils, and starter-drive assembly must not be washed in solvent. Check starter frame for thrown solder from the armature-commutator connections.)

2. Arrange all starter components for inspection

3. Check starter bushings for looseness and replace as required

4. Check starter brushes for wear

   (NOTE: Brushes worn to one-half their original length or more should be replaced.)

5. Check the starter drive

   a. Check gear teeth for wear

   b. Check bushings for wear

   c. Check starter-drive pinion gear to make sure that it turns freely in one direction and locks when turned in the other direction

6. Inspect armature commutator and recondition as required

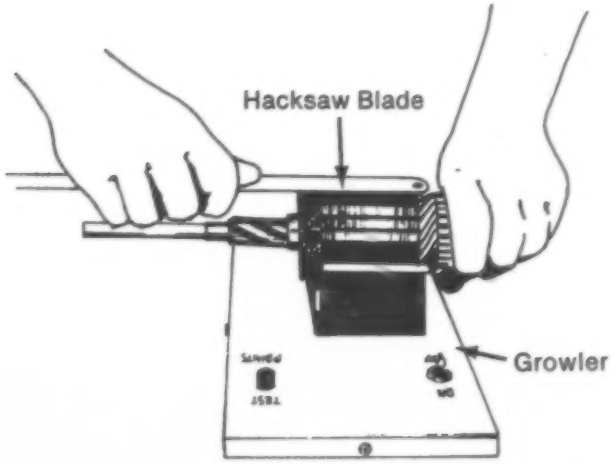
   (NOTE: If the armature commutator is rough or out of round, it should be turned down using suitable equipment.)

JOB SHEET #14

7. Check armature for short circuits (Figure 62)

(NOTE: Place the armature on the growler and rotate the armature while holding a hacksaw blade over its core. If the blade vibrates, the armature is shorted and will require replacement.)

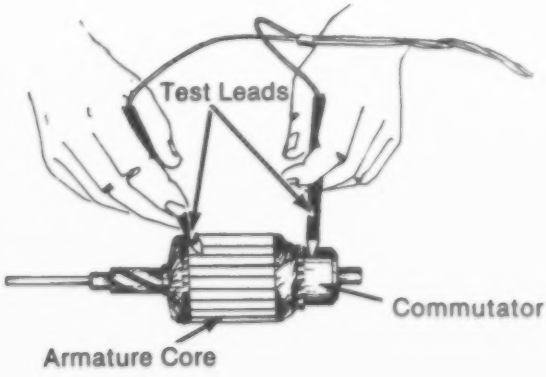
FIGURE 62



8. Check armature for ground (Figure 63)

(NOTE: Place one lead of a test lamp on the armature core or shaft and the other on each segment of the commutator. If the lamp lights, the armature is grounded and will require replacement.)

FIGURE 63

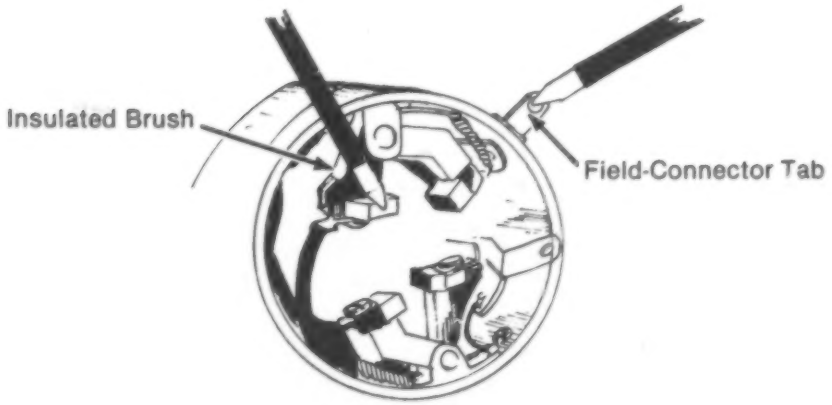


JOB SHEET #14

9. Check field coil for open circuit (Figure 64)

(NOTE: Place one lead of the test lamp on the insulated brush and the other on the field-connector tab. If the lamp does not light, the field coils are open and will require replacement.)

FIGURE 64



10. Check field coil for ground (See Figure 65)

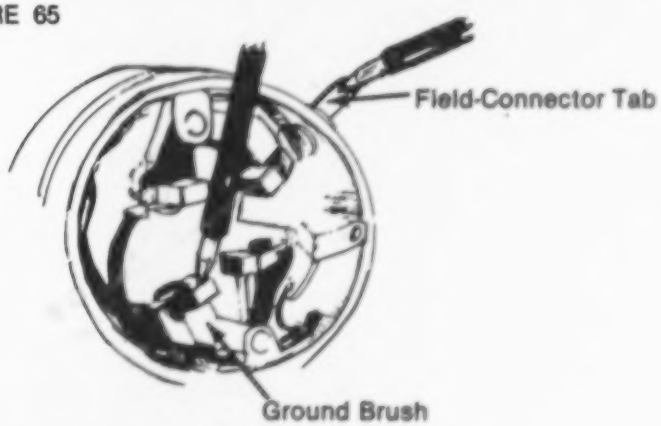
a. Disconnect shunt field and/or self-energizing switch and insulate from starter frame if so equipped

b. Check shunt field by touching one test-lamp lead to either of the shunt-field wires; touch other test-lamp lead to starter frame

c. Check field coils by touching one test-lamp lead to field connector tab or post and the other lead to starter frame

(NOTE: If the lamp lights in either test, the field coils are grounded and will require replacement.)

FIGURE 65



(NOTE: After all parts have been tested and inspected and worn or damaged parts have been replaced, the starter is ready to be reassembled.)

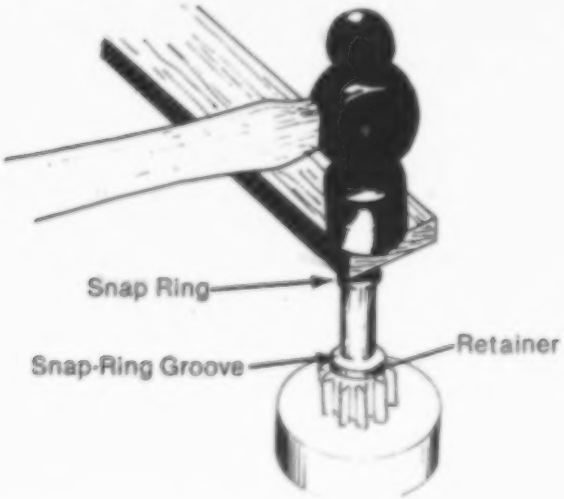
C. Reassemble starter

1. Assemble and install starter brush rigging if required
2. Attach wires to starter brush assemblies
3. Install assist spring on armature shaft
4. Install starter drive on armature shaft

JOB SHEET #14

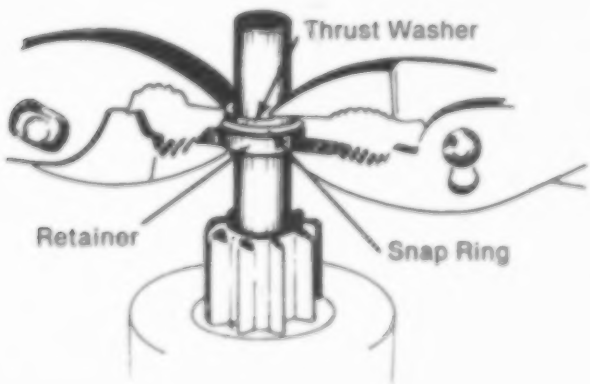
5. Install retainer and snap ring (Figure 66)

FIGURE 66



6. Force snap ring into retainer (Figure 67)

FIGURE 67



7. Lubricate drive-housing bushing with four to five drops of light oil

8. Make sure that thrust collar is in place against snap ring and retainer

9. Slide armature and starter drive assembly into place in drive housing, engaging shift lever with starter drive as required

(NOTE: Install solenoid if removed.)

10. Position field frame over armature

    (NOTE: Use care when positioning field frame against drive housing to prevent damage to the brushes.)

11. Place four to five drops of light oil on starter end-frame bushing

12. Place leather brake washer on armature shaft

13. Install starter end frame; start through bolts

    (NOTE: Align lugs on the starter frame with drive-housing hole. Align end-frame lug with starter-housing slot before tightening through bolts.)

14. Tighten through bolts evenly and securely

15. Reconnect the field-coil connectors to solenoid

16. Test starter with a battery and jumper cables to determine starter performance

D. Clean work area; clean and put away all tools and equipment

ELECTRICAL SYSTEMS
UNIT V

JOB SHEET #15 — CHECK AND SET IGNITION TIMING

I. Equipment and materials

A. Vehicle

B. Timing light

C. Combination wrenches, 7/16 inch to 9/16 inch

D. Special distributor wrenches as required

E. Shop towels

F. Chalk

G. Safety glasses

H. Appropriate service manual

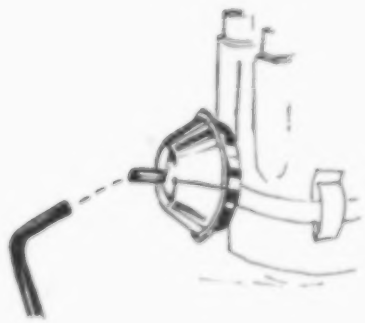
II. Procedure

A. Obtain manufacturer's specifications for ignition timing, dwell, and revolutions per minute

(NOTE: Dwell and revolutions per minute must be set to manufacturer's specifications before timing is set.)

B. Remove vacuum line at distributor (Figure 68)

FIGURE 68



C. Locate and clean ignition timing marks on harmonic balancer; mark with chalk

D. Locate and clean timing pointer or plate on front cover

JOB SHEET #15

E. Connect timing light according to instructions for light being used

(NOTE: Do not puncture spark-plug cables with pins or clips to make connections.)

F. Position wires away from moving engine parts

G. Start engine

H. Make sure that engine idles at manufacturer's recommended speed

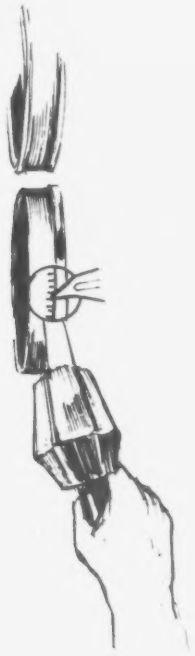
(NOTE: The engine must idle correctly to prevent incorrect timing caused by the centrifugal advance.)

I. Check ignition timing and adjust as required

1. Direct timing light toward timing marks (Figure 69)

(NOTE: If the timing is correct, the timing marks will line up at the check point. If the timing is incorrect, proceed as follows.)

FIGURE 69



2. Loosen clamp or lock-screw on distributor

JOB SHEET #15

3. Move distributor until timing marks are aligned (Figure 70)

FIGURE 70

4. Tighten clamp or lock-screw on distributor

J. Recheck timing

K. Shut off engine

L. Disconnect timing light

(NOTE: Remove timing-light adapter on spark plug if used.)

M. Replace vacuum line on distributor

N. Clean work area; clean and put away all tools and equipment

ELECTRICAL SYSTEMS
UNIT V

JOB SHEET #16 — REMOVE AND REPLACE A DISTRIBUTOR

I. Equipment and materials

A. Vehicle

B. Basic hand-tool set

C. Special distributor wrenches as required

D. Auxiliary starter button

E. Safety glasses

II. Procedure

A. Open engine compartment (where applicable)

B. Remove air cleaner if required

C. Remove distributor wire from coil or distributor as required

D. Remove distributor cap and place out of the way

E. Check position of rotor

(NOTE: To aid reinstallation, mark or in some way indicate the position of the rotor.)

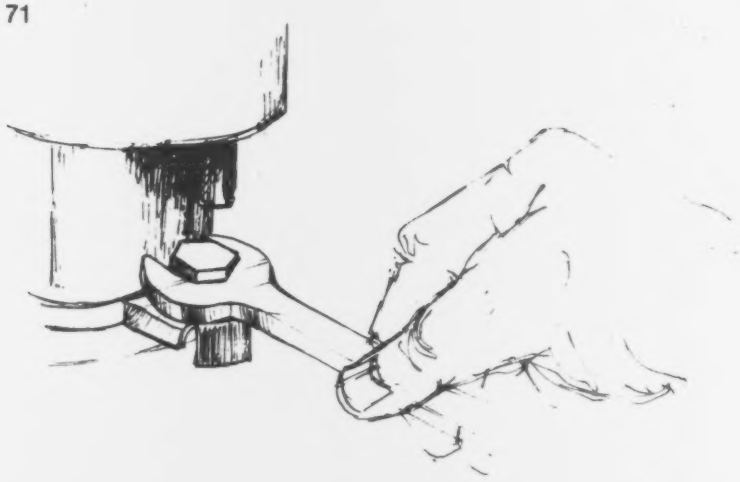
F. Remove vacuum-hose line from distributor

JOB SHEET #16

G. Remove distributor clamp screw and hold-down clamp (Figure 71)

(NOTE: Mark position of distributor to aid replacement. Blow or brush away foreign material around distributor base.)

FIGURE 71



H. Pull distributor up slowly and check direction the rotor turns

(NOTE: For proper reinstallation, you must know the amount the rotor turns and the direction it turns.)

I. Remove distributor from engine

(CAUTION: Avoid dropping bolts, brackets, or foreign material into opening. Cover opening with a shop towel.)

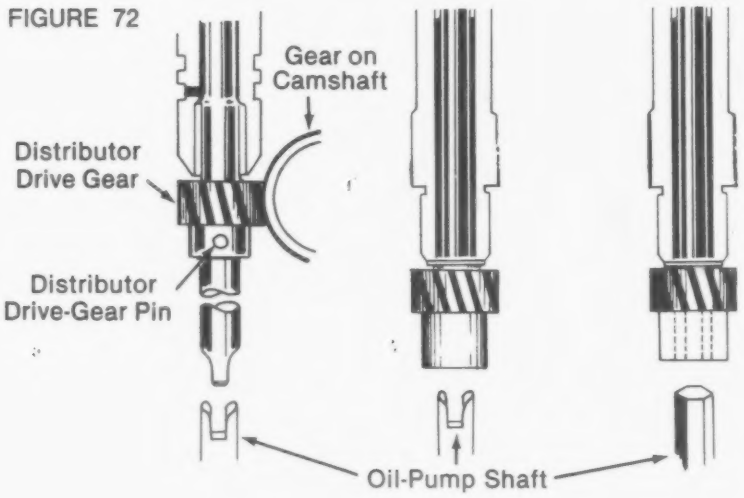
J. Service distributor as required

JOB SHEET #16

K. Install distributor in opening

(NOTE: The rotor must be pointing in the same direction it was before removal. Occasionally, the distributor will not fall into place because the oil-pump shaft has moved. The rotor should be positioned as closely as possible to the beginning location, and the engine should be rotated slightly until the distributor falls into place; see Figure 72)

FIGURE 72



L. Install hold-down clamp and clamp screw

M. Tighten hold-down screw slightly

N. Replace vacuum lines if necessary and reinstall

O. Reinstall distributor cap and wires if removed

P. Reinstall distributor lead wire

Q. Check all connections for correct placement

R. Start engine and set timing

(NOTE: If the engine was turned while the distributor was removed, retime the engine. Use the following steps.)

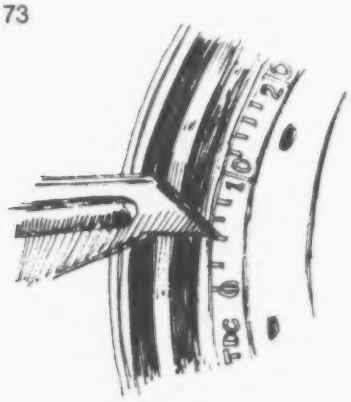
S. Set distributor basic timing

1. Remove number-one cylinder spark plug

2. Install auxiliary starter button, and crank the engine until compression is felt on number-one cylinder

3. Crank engine with short movements until timing marks on harmonic balancer index with timing marks on front cover (Figure 73)

FIGURE 73



4. Reinstall distributor in engine, with rotor pointing toward number-one spark-plug wire in distributor cap and with contact points ready to open

T. Reinstall all hoses, wires, and hold-down clamp

U. Reinstall spark plug and spark-plug wire

V. Start engine

W. Set timing

X. Clean work area; clean and put away all tools and equipment

ELECTRICAL SYSTEMS
UNIT V

JOB SHEET #17 — REMOVE AND REPLACE CONTACT POINTS AND CONDENSER

I. Equipment and materials

- A. Vehicle
- B. Ignition wrenches
- C. Feeler gauges, 0.010 inch to 0.025 inch
- D. Screwdrivers as required
- E. Distributor cam lubricant
- F. Shop towel
- G. Point-alignment tools
- H. Spring gauge
- I. Timing light
- J. Safety glasses
- K. Appropriate service manual

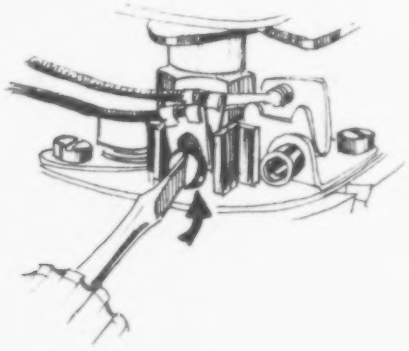
II. Procedure

- A. Remove distributor cap and place out of the way
- B. Remove rotor
- C. Determine condition of contact points and locations of wires, screws, and eccentric

JOB SHEET #17

D. Disconnect contact-point primary lead wire and condenser wire by loosening attaching screw (Figure 74)

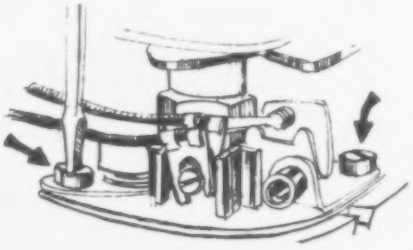
FIGURE 74



E. Remove screws holding contact points in place (Figure 75)

(NOTE: Some points have slotted holes that will allow points to be removed with attaching screws loosened two to three turns.)

FIGURE 75



F. Remove contact-point set

G. Remove screw holding condenser in place

H. Remove condenser

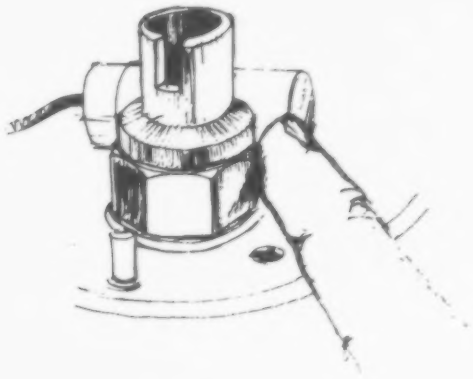
I. Clean breaker plate and distributor cam

JOB SHEET #17

J. Lubricate distributor cam with a light coat of cam lubricant (Figure 76)

(NOTE: On distributors with the centrifugal weights accessible, place a drop of light oil on each weight pivot post.)

FIGURE 76



K. Place contact points in distributor; install attaching screw

L. Reinstall condenser and attaching screw; tighten securely

M. Reinstall primary lead and condenser wires

(NOTE: Position the wires to avoid binding or grounding.)

N. Tighten primary lead and condenser wires securely

O. Check point alignment and adjust as required

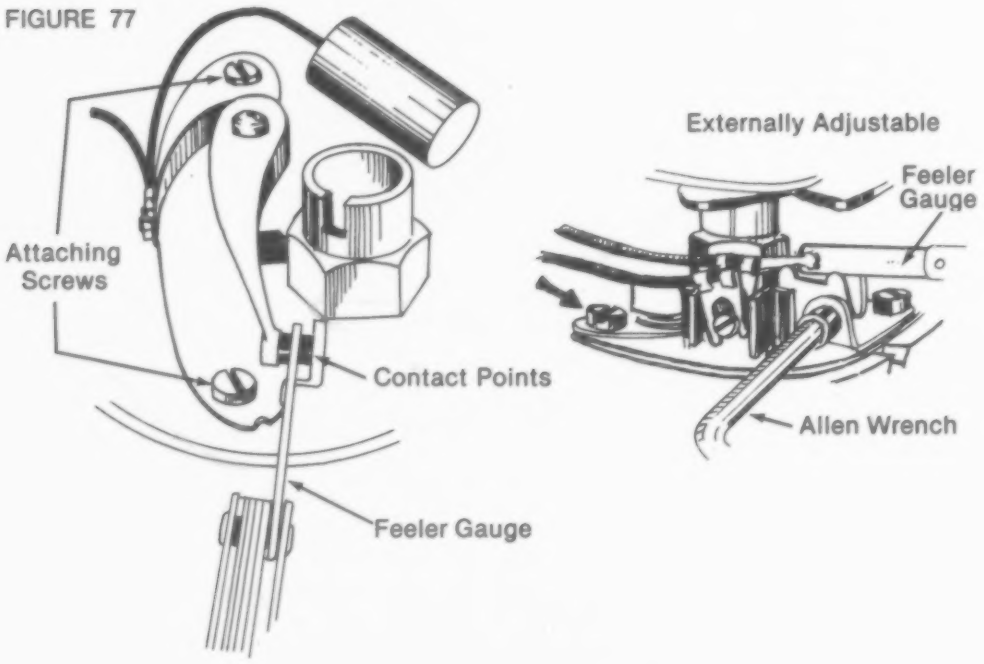
P. Check contact-point-breaker spring tension

JOB SHEET #17

Q. Adjust contact-point opening (Figure 77)

(NOTE: Crank the engine to position the rubbing block of the contact points on the peak of a cam lobe. The externally adjustable points can be more accurately and easily set with a dwell meter while the engine is running. Refer to Job Sheet #18.)

FIGURE 77



S. Tighten contact-point attaching screws securely; recheck contact-point opening

T. Install rotor

(NOTE: Make sure that the rotor is positioned correctly and is held securely in place.)

U. Install distributor cap

(NOTE: Make sure that distributor is positioned correctly and is held securely in place.)

V. Replace distributor in engine

W. Start engine

JOB SHEET #17

X. Set timing to manufacturer's specifications (Figure 78)

(NOTE: Refer to engine service manual for specifications.)

FIGURE 78

Y. Clean work area; clean and put away all tools and equipment

ELECTRICAL SYSTEMS
UNIT V

JOB SHEET #18 — ADJUST DWELL ON AN EXTERNALLY ADJUSTABLE DISTRIBUTOR

I. Equipment and materials

A. Vehicle

B. Dwell meter

C. Hex wrench for contact-point adjusting

D. Safety glasses

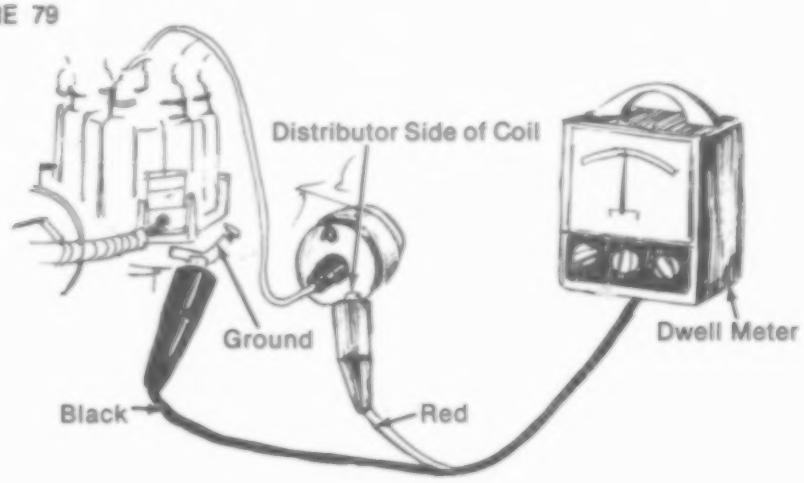
E. Appropriate service manual

II. Procedure

A. Hook up dwell meter

(NOTE: Observe correct hookup procedures and position wires away from moving engine parts; see Figure 79)

FIGURE 79



B. Refer to manufacturer's specifications for desired dwell setting

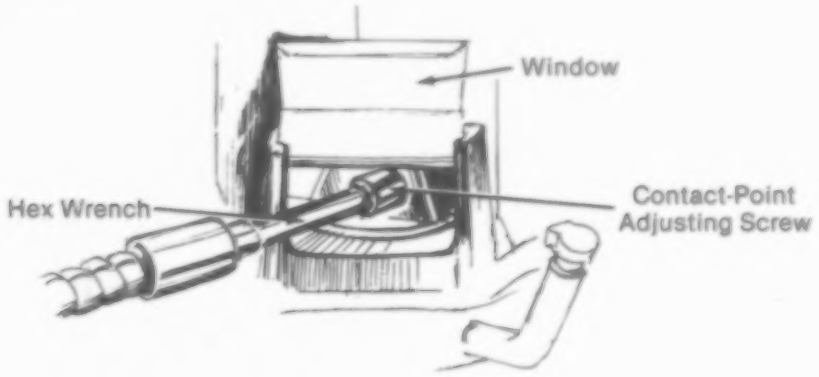
C. Start engine

D. Raise distributor-cap adjustment window

JOB SHEET #18

E. Insert hex wrench into contact-point adjustment screw (Figure 80)

FIGURE 80



F. While observing dwell-meter reading, adjust contact-point dwell to comply with manufacturer's specifications

G. Remove hex wrench and recheck dwell reading

H. Shut off engine

I. Remove dwell meter

J. Push window on distributor cap down securely

K. Clean work area; clean and put away all tools and equipment

ELECTRICAL SYSTEMS
UNIT V

JOB SHEET #19 — TEST AND ADJUST DISTRIBUTOR ON DISTRIBUTOR TESTER

I. Equipment and materials

A. Distributor tester

B. Distributor without cap

C. Screwdriver set

D. Ignition-wrench set

E. Cam lubricant

F. Light motor oil

G. Spring tension gauge

H. Dwell meter

I. Breaker-point bending tool

J. Appropriate service manual

II. Procedure

A. Inspect distributor visually for the following conditions

1. Shaft for end play

2. Distributor drive for wear or damage

3. Shaft and bearings for wear

4. Breaker plate for smooth operation and excessive looseness

5. Insulators and lead wires for damage or wear

B. Mount distributor in tester (See Figure 81)

1. Raise clamp arms high enough to permit distributor shaft to clear drive chuck

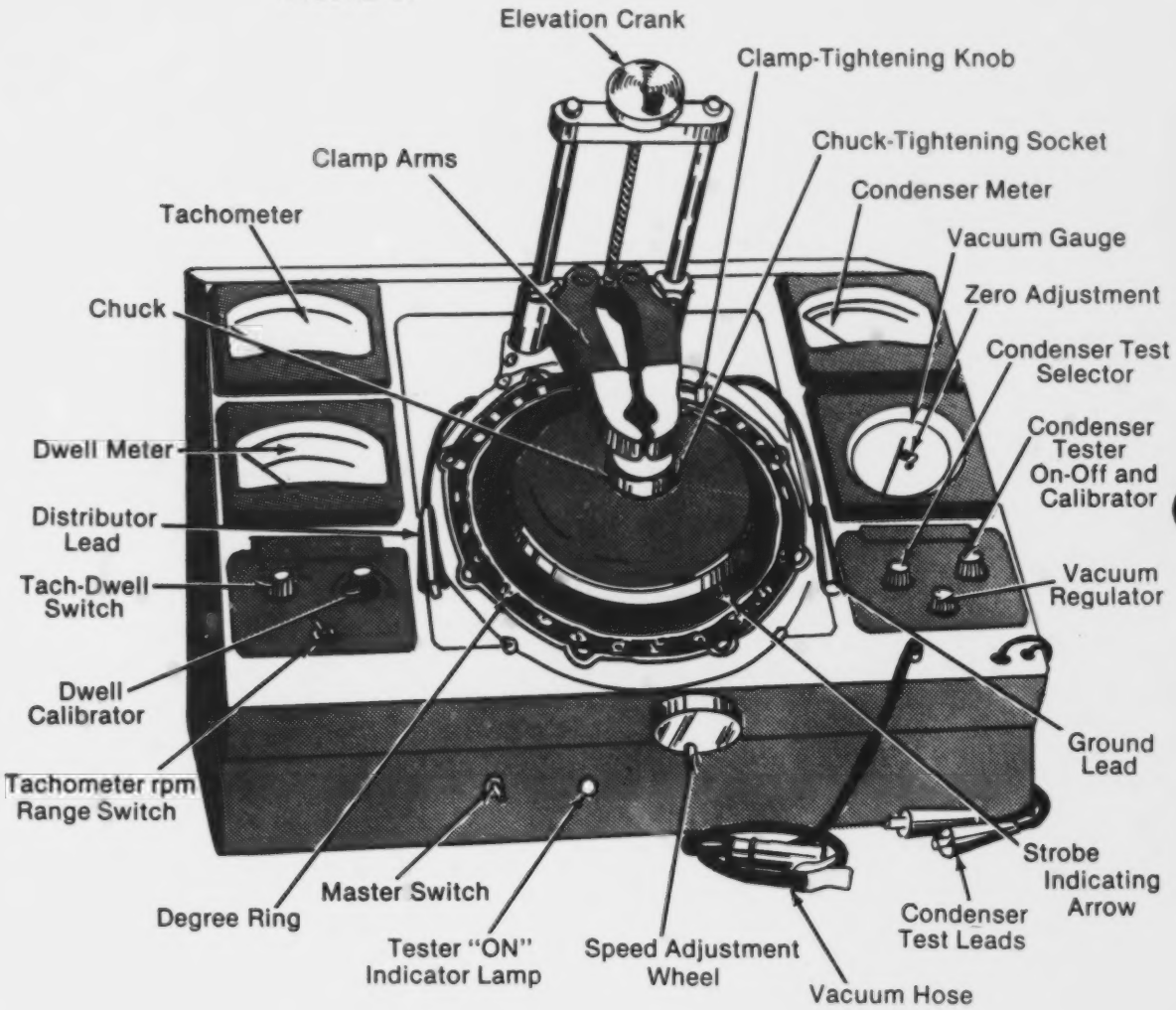
2. Position distributor in clamp with vacuum chamber to right side; tighten clamp on distributor case

(NOTE: The distributor should be mounted so that it aligns well with the drive chuck and the shaft is free to turn.)

3. Lower shaft into drive chuck; tighten chuck

(NOTE: The distributor shaft should be approximately centered from top to bottom in the drive chuck.)

FIGURE 81



C. Test condenser

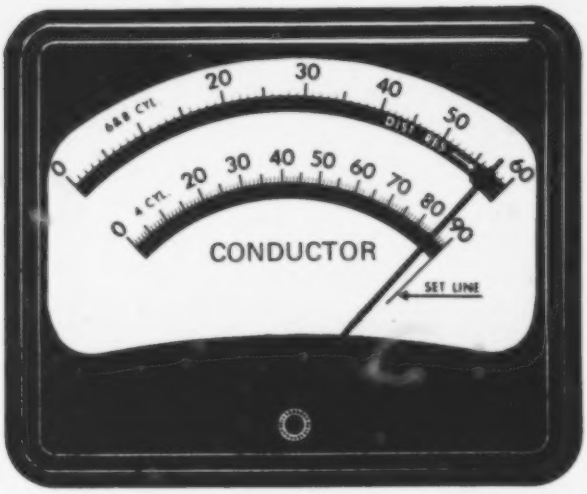
1. Set drive switch in position for direction of rotation of distributor
2. Set speed to zero revolutions per minute
3. Connect condenser test leads

JOB SHEET #19

4. Set condenser-test selector switch in series-resistance position and allow to warm up for approximately thirty seconds

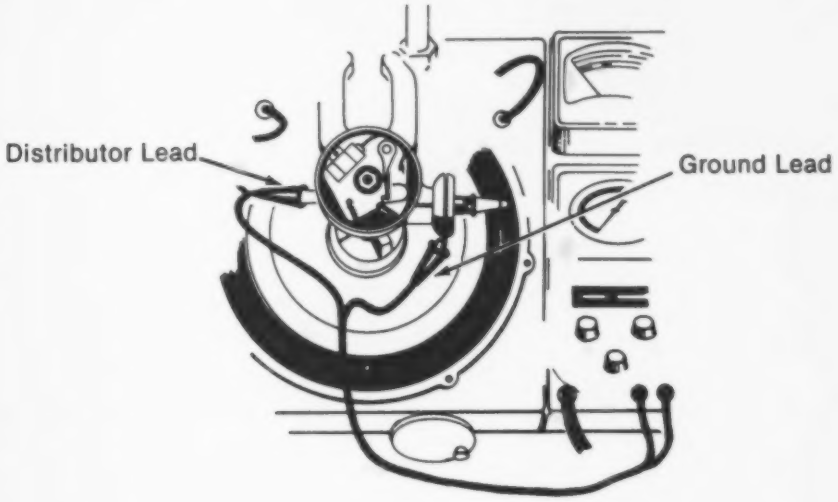
5. Adjust calibration control until meter reads on set line (Figure 82)

FIGURE 82



6. Separate leads and connect one to distributor primary lead and other to distributor case (Figure 83)

FIGURE 83



7. Rotate distributor shaft until cam holds breaker points open

8. Test series resistance with test selector switch in resistance position

   (NOTE: The meter should read in the black bar at the right end of the scale.)

9. Test condenser capacity with test selector switch in capacity position

   (NOTE: Compare with manufacturer's specifications.)

10. Test condenser leakage with selector switch in leakage position

    (NOTE: The meter should read in the black bar at the left end of scale.)

11. Set test selector to series-resistance and turn condenser calibration to OFF before disconnecting test leads

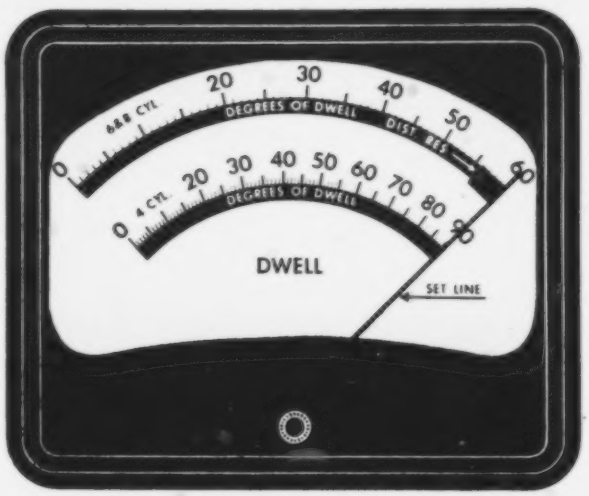
D. Test distributor resistance

1. Position motor switch in proper distributor rotation with speed control set to zero revolutions per minute

2. Connect tester leads

3. Set tach-dwell selector switch to calibrate position, and adjust dwell regulator until dwell meter reads on the set line (Figure 84)

FIGURE 84



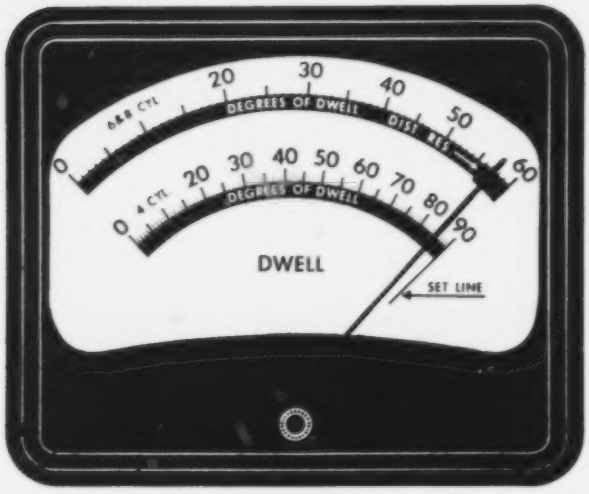
JOB SHEET #19

4. Separate leads; connect distributor lead to distributor primary terminal and ground lead to distributor body

5. Close breaker points

(NOTE: The dwell-meter pointer should read within the range of the black bar at end of scale. A dwell-meter pointer reading out of the black bar indicates excessive resistance in the distributor primary circuit. For distributors with two sets of breaker points, test the resistance of each set separately by holding one set open while testing the other; see Figure 85)

FIGURE 85



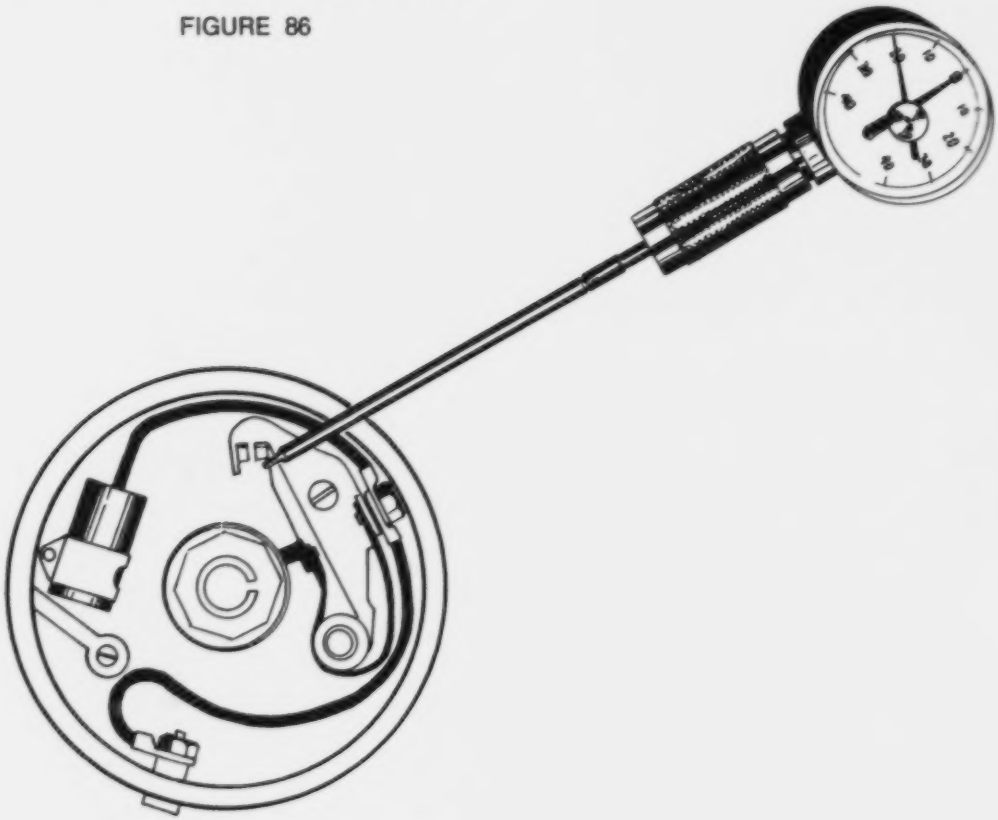
JOB SHEET #19

E. Test breaker-point spring tension

(NOTE: The dwell meter should be calibrated and test leads connected as for distributor-resistance test.)

1. Position hook of spring tension gauge near contact of movable breaker point (Figure 86)

FIGURE 86



2. Pull spring tension gauge slowly at right angles to point lever

3. Note reading on spring tension gauge at the exact time points open, as indicated by the dwell-meter reading that will fall to zero

JOB SHEET #19

4. With spring tension gauge, hold points open to approximately the normal gap; then slowly let points close

   (NOTE: The gauge reading should not decrease noticeably from the previous reading before the points close. If the reading does decrease noticeably, the breaker-point pivot requires lubrication or replacement. Dual-point distributors must have one set blocked open while testing the other set.)

F. Test cam-lobe accuracy

1. Connect test leads to distributor lead and distributor body
2. Turn tach-dwell switch to position corresponding with the number of engine cylinders
3. Adjust distributor speed to 1,000 revolutions per minute
4. Rotate degree ring of tester until the zero on ring is aligned with one of the arrow flashes

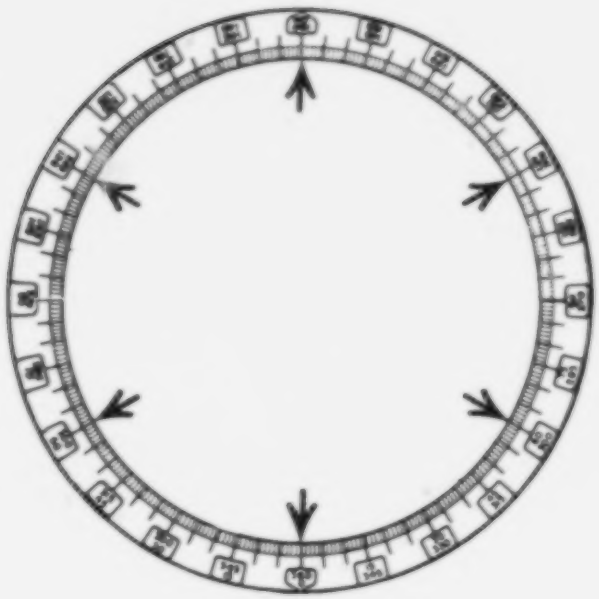
JOB SHEET #19

5. Observe position of all flashing arrows

(NOTE: All arrow flashes should be evenly spaced around the degree ring within ±1 degree; see Figure 87.)

90 degrees apart on four-lobe cams
60 degrees apart on six-lobe cams
45 degrees apart on eight-lobe cams

FIGURE 87



JOB SHEET #19

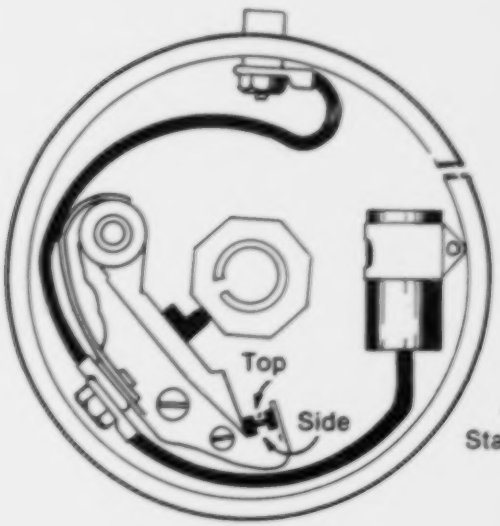
G. Test breaker-point alignment

(NOTE: The tester will be set up the same as for the previous test.)

1. Observe the slight arc appearing between breaker points

(NOTE: The points are properly aligned when the arc appears in the center of the contact when observed from above and from the side; see Figure 88.)

FIGURE 88



Center Arc on Point

2. Reduce distributor speed to 200 revolutions per minute

3. Align breaker points with special bending tool

H. Adjust breaker-point dwell

1. Observe dwell meter and compare reading with specifications

2. Adjust dwell by moving stationary point toward or away from distributor cam

(NOTE: On dual-point distributors, you must isolate one point set with piece of clean fiber while setting the other point set.)

JOB SHEET #19

I. Test breaker-point dwell variation — Observe dwell-meter readings while varying distributor speed from 200 to 1,750 revolutions per minute

(NOTE: Dwell variation in excess of 2 degrees indicates a worn distributor shaft or bushings.)

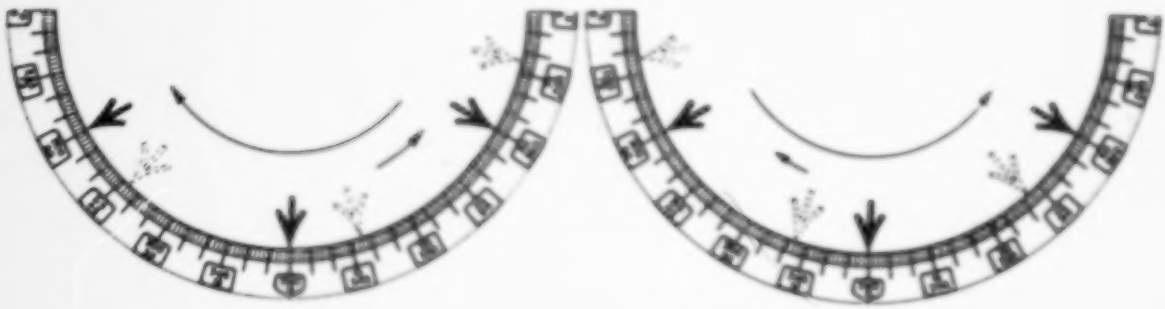
J. Test centrifugal advance calibration

(NOTE: This test is made to determine whether the ignition timing conforms to the manufacturer's specified advance curve at all engine operating speeds.)

1. Set up tester as for the cam-lobe accuracy test
2. Set speed at 200 revolutions per minute
3. Set degree ring zero to its nearest flashing arrow
4. Increase distributor speed to each consecutive speed and note amount of advance for each (Figure 89)

(NOTE: The amount of advance should be within ±1° of specifications if no range is given.)

FIGURE 89



5. Momentarily exceed highest specified speed given; then reduce distributor speed to zero while noting the advance for each specified speed as a second test

(NOTE: If advance is excessive, the governor weight springs are weak or the wrong springs are installed. If advance is slow on acceleration and excessive on deceleration, the governor weights are sticking. If advance is insufficient both on acceleration and deceleration, governor weight spring tension is excessive.)

JOB SHEET #19

K. Test vacuum chamber diaphragm for leakage

1. Attach vacuum test hose to vacuum unit
2. Seal hose with shut-off clamp
3. Adjust vacuum regulator until meter reads 15 inches
4. Release hose clamp and observe meter

(NOTE: If the meter reading momentarily falls to a lower reading and then returns to 15 inches within a few seconds, the chamber is air tight.)

L. Test vacuum-controlled breaker plate

(NOTE: The breaker plate should be smooth and even in travel to maintain proper dwell and timing advance.)

1. Adjust speed control to 1,000 revolutions per minute
2. Adjust vacuum regulator to zero; increase vacuum to 20 inches while watching the dwell-meter pointer for variations

(NOTE: On center-pivot breaker plates, variation should not exceed 2 degrees. On side-pivot breaker plates, the dwell will vary more than 2 degrees but not over 10 degrees. The plate should twist evenly through its full travel and remain stable.)

M. Test vacuum spark advance

1. With no vacuum applied, set the degree ring zero in line with one of the arrows (Figure 90)

FIGURE 90

2. Adjust vacuum regulator to apply proper amount of vacuum for each specified check point; note amount of advance obtained

3. Momentarily exceed the highest vacuum value specified; reduce vacuum and again note advance obtained at each specified checkpoint

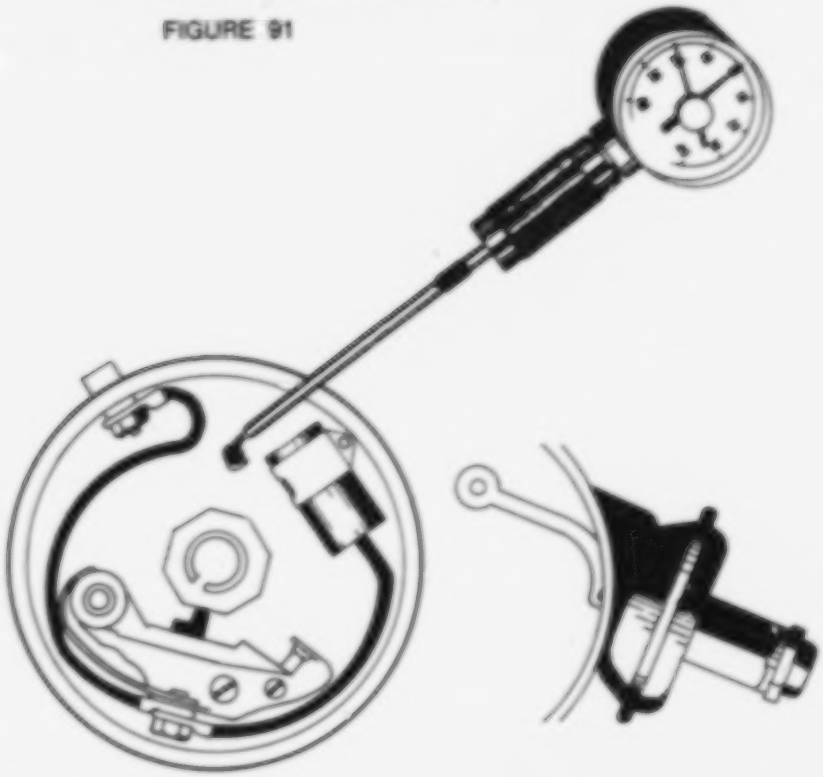
(NOTE: If advance is excessive during both steps 2 and 3, a weak advance spring is indicated. If advance is insufficient during steps 2 and 3, an excessively strong advance spring is indicated. If advance is insufficient in step 2 and excessive in step 3 or is erratic in both steps, the distributor plate is sticking or binding.)

N. Test breaker-plate spring tension

1. Remove vacuum advance unit from distributor

2. Hook spring tension scale on breaker plate where advance-unit push rod was attached (Figure 91)

FIGURE 91



JOB SHEET #19

3. Note amount of pull necessary to start movement of breaker plate from fully retarded position

(NOTE: Refer to manufacturer's specifications for the maximum amount of pull allowed.)

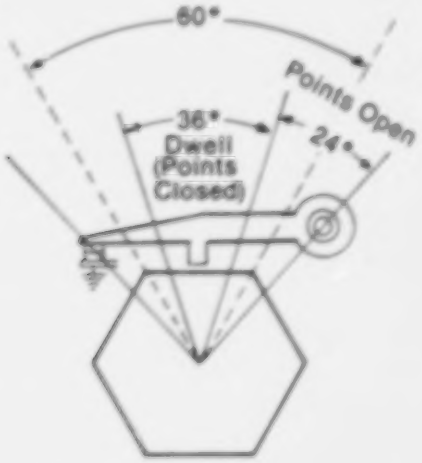
O. Adjust breaker-point gap or dwell angle

1. Loosen breaker-point retainer screws enough to allow points to be moved yet still maintain their positions while in operation

(NOTE: Some points are adjusted by a screw positioned between the stationary point and the assembly base so that the attaching screws will remain tight.)

2. Increase open gap between breaker point to reduce dwell reading, and decrease open gap between breaker points to increase dwell reading (Figure 92)

FIGURE 92



Dotted Lines Indicate the 60 Degrees Between
Cam Lobes Alloted to the Firing
of Each Cylinder of a Six-Cylinder Engine

Six-Cylinder Cam

P. Clean work area; clean and put away all tools and equipment

ELECTRICAL SYSTEMS
UNIT V

JOB SHEET #20 — REMOVE, INSPECT, SERVICE, AND REPLACE SPARK PLUGS

I. Equipment and materials

A. Vehicle

B. Spark-plug socket with 3/8-inch drive

C. Ratchet with 3/8-inch drive

D. 3-inch, 6-inch, and 10-inch extensions with 3/8-inch drive

E. Spark-plug cleaning machine

F. Wire brush

G. Small-point file

H. Shop towels

I. Plug gauge

J. Safety glasses

K. Appropriate service manual

II. Procedure

A. Remove spark-plug wires

(NOTE: Pull the wire from the spark plug by grasping the terminal, not by pulling on the wire.)

B. Loosen spark plugs

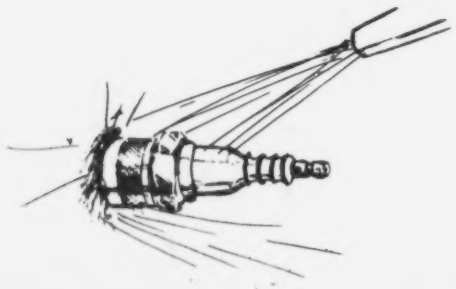
JOB SHEET #20

C. Clean area around the spark plug by blowing, wiping, or brushing (Figure 93)

(NOTE: Loosen the spark plug approximately two turns and crank the engine so that the compression going past the spark-plug threads will clean the dirt and grit from the plug seat area.)

(CAUTION: Protect your eyes when using compressed air.)

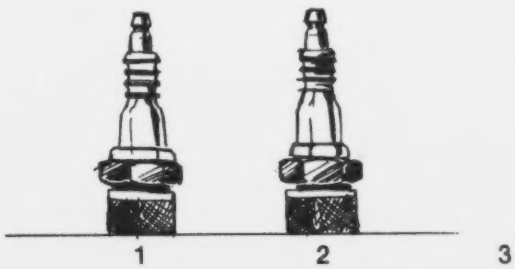
FIGURE 93



D. Remove spark plugs

(NOTE: Arrange the spark plugs in order as they are removed. The condition of the spark plug can tell a lot about the operation of a particular cylinder; see Figure 94.)

FIGURE 94



E. Remove spark-plug gaskets if required

F. Determine condition of spark plugs and decide whether to replace or service them

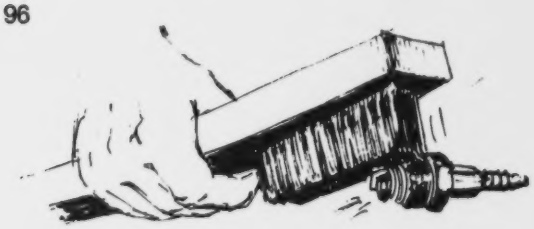
JOB SHEET #20

G. Clean spark plugs on a spark-plug cleaning machine (Figure 95)

FIGURE 95

H. Clean threads with wire brush (Figure 96)

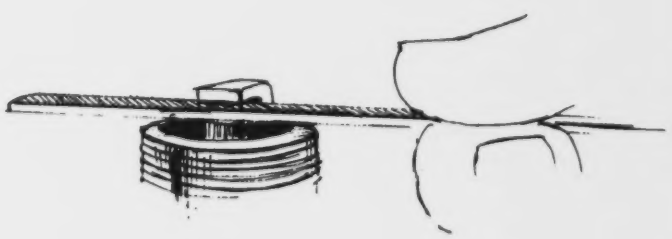
FIGURE 96



I. Bend ground electrode slightly to open gap

J. File center electrode to flatten surface and square edges (Figure 97)

FIGURE 97



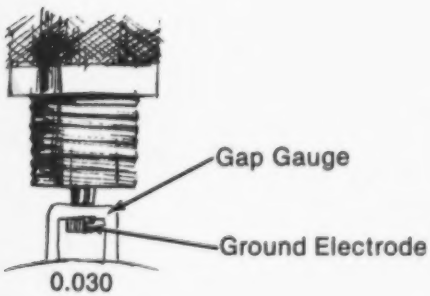
JOB SHEET #20

K. Reset gaps of new and serviced spark plugs to manufacturer's specifications (Figure 98)

(NOTE: Use wire gauge to check the gap. Make sure that electrode surfaces are parallel.)

(CAUTION: Bend only the ground electrode.)

FIGURE 98



L. Install new spark-plug gaskets as required

M. Install spark plugs and tighten

(NOTE: Use caution when starting the spark plugs to avoid cross-threading.)

N. Torque spark plugs to manufacturer's recommendations

(CAUTION: Take care not to overtorque spark plugs with tapered sealing surfaces because the plugs will be damaged.)

O. Replace spark-plug wires in proper order

(NOTE: Push the spark-plug wires securely into place and make sure that they are in the brackets or holders.)

P. Clean work area; clean and put away all tools and equipment

ELECTRICAL SYSTEMS
UNIT V

JOB SHEET #21 — REMOVE AND REPLACE A GENERATOR

I. Equipment and materials

A. Vehicle

B. Basic hand-tool set

C. Suitable pry bar

D. Belt tension gauge

E. Jumper wires

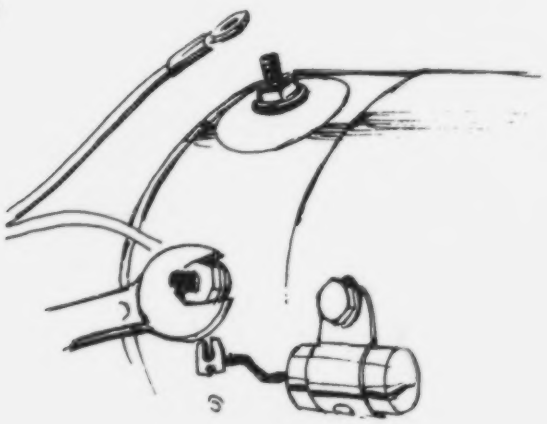
F. Safety glasses

G. Appropriate service manual

II. Procedure

A. Remove leads from generator terminals (Figure 99)

FIGURE 99

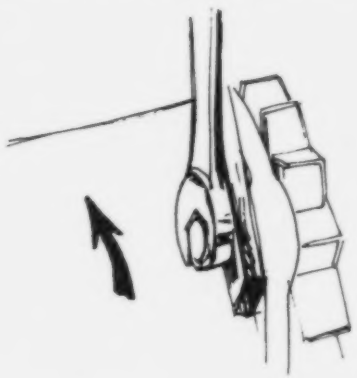


B. Remove generator-belt adjusting bolt

JOB SHEET #21

C. Move generator toward engine (Figure 100)

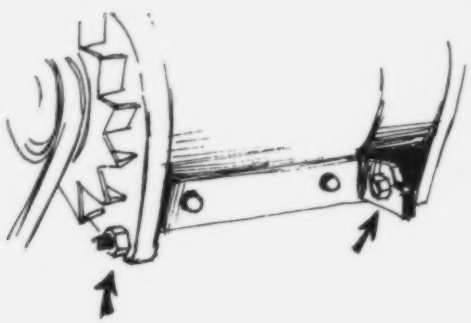
FIGURE 100



D. Remove generator belt from generator pulley

E. Remove bolts holding generator to engine mounting bracket (Figure 101)

FIGURE 101



F. Lift generator out of bracket

G. Service generator as required

H. Position generator in engine mounting bracket

I. Start generator retaining bolts and tighten lightly

J. Position generator belt on pulley and move generator away from engine to tighten belt

K. Install generator adjusting bolt

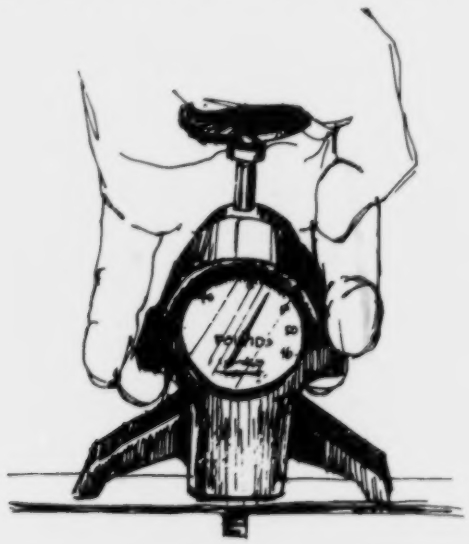
JOB SHEET #21

L. Pry generator away from engine to adjust generator belt; tighten adjusting bolt and mounting bolts securely

M. Check generator-belt tension with a belt tension gauge and readjust if not within manufacturer's specifications (Figure 102)

(NOTE: The generator belt must be adjusted properly.)

FIGURE 102



N. Reinstall wire leads that were removed from generator

(NOTE: On vehicles using a condenser on the generator, the condenser lead is attached to the "A" terminal — never to the "F" terminal.)

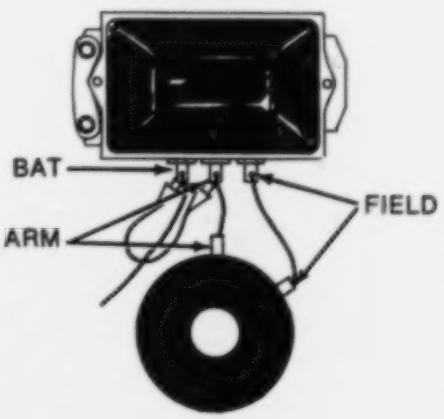
JOB SHEET #21

O. Polarize generator before starting engine

1. Polarize "A" circuit generators by holding one end of a jumper wire against the regulator BAT terminal and momentarily touching the other end of jumper wire to the regulator ARM or GEN terminal (Figure 103)

FIGURE 103

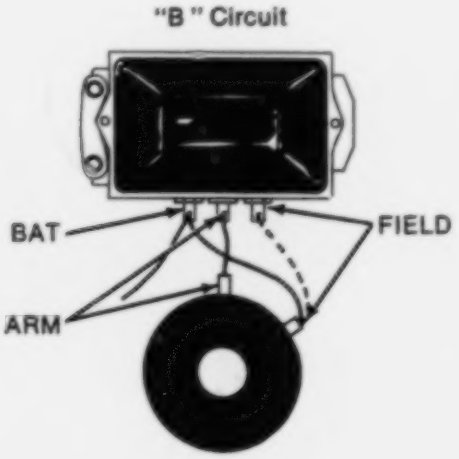
"A" Circuit



JOB SHEET #21

2. Polarize "B" circuit generators by removing the lead from the FIELD terminal of the regulator and momentarily touching the "F" lead to the BAT terminal of regulator (Figure 104)

FIGURE 104



P. Clean work area; clean and put away all tools and equipment

ELECTRICAL SYSTEMS
UNIT V

JOB SHEET #22 — DISASSEMBLE, CHECK, AND REASSEMBLE A GENERATOR

I. Equipment and materials

A. Generator, removed from vehicle

B. Basic hand-tool set

C. Shop towels

D. Suitable armature and field testing equipment

E. Generator pulley puller

F. Safety glasses

G. Hacksaw blade

H. New brushes

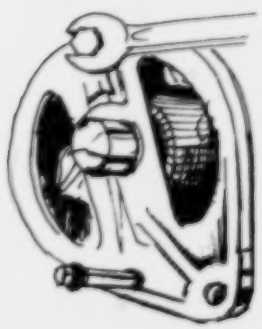
I. Appropriate service manual

II. Procedure

A. Disassemble generator

1. Remove generator through-bolts (Figure 105)

FIGURE 105

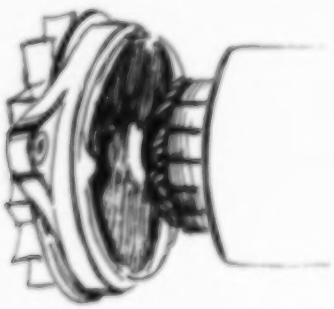


JOB SHEET #22

2. Tap generator commutator end frame lightly and remove from housing

3. Remove drive end frame and armature assembly from generator housing (Figure 106)

FIGURE 106



4. Remove generator brushes (Figure 107)

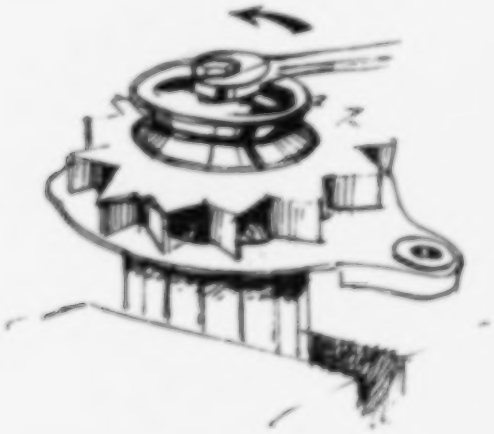
FIGURE 107

5. Place armature and drive end-frame assembly in a vise (See Figure 108)

JOB SHEET #22

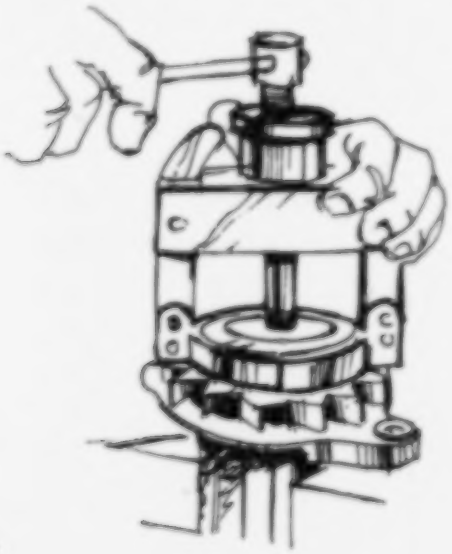
6. Remove pulley nut (Figure 108)

FIGURE 108



7. Remove pulley from armature, using a pulley puller as required (Figure 109)

FIGURE 109



8. Slide drive end frame and spacer columns off armature shaft

9. Remove armature from vise

10. Remove bearing retainer and gasket from drive end frame

11. Remove drive end bearing from drive end frame

B. Clean and inspect generator

1. Clean all generator components

(CAUTION: Do not wash the fields or armature with a degreasing solvent.)

2. Inspect generator drive end-frame bearings for roughness or scored races

3. Inspect generator brush holders to see whether they are bent or deformed; check generator brush springs for proper spring tension

4. Check fit of armature shaft in bushing in commutator end frame

(NOTE: If bushing is excessively worn, the end frame should be replaced.)

5. Inspect armature commutator for roughness or out-of-round condition

(NOTE: If armature commutator is rough or out of round, it should be turned or serviced on an armature turning lathe.)

6. Test armature for shorts (See Figure 110)

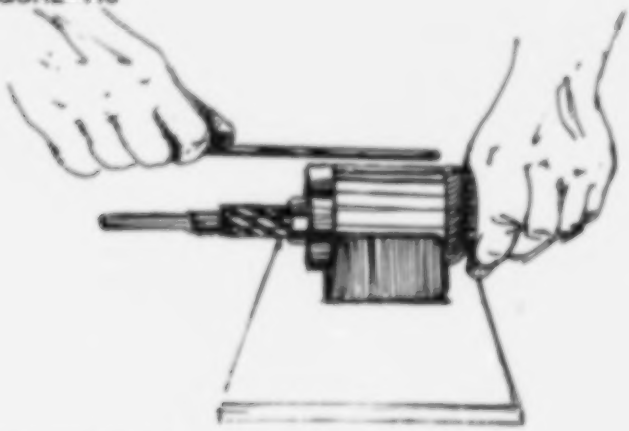
a. Place armature on growler

JOB SHEET #22

b. Rotate armature while holding a hacksaw blade over armature core (Figure 110)

(NOTE: If the blade vibrates, the armature is shorted and will require replacement.)

FIGURE 110



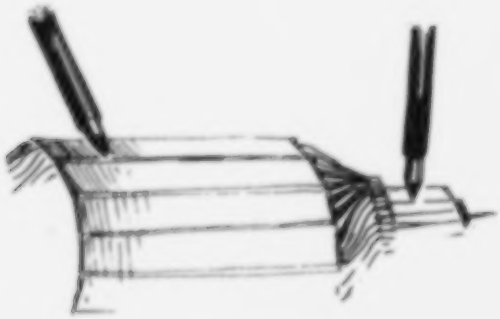
7. Test armature for ground (Figure 111)

a. Place one test lamp lead on armature core or shaft

b. Place the other test lamp lead on commutator

(NOTE: If the lamp lights, the armature is grounded and will require replacement.)

FIGURE 111



JOB SHEET #22

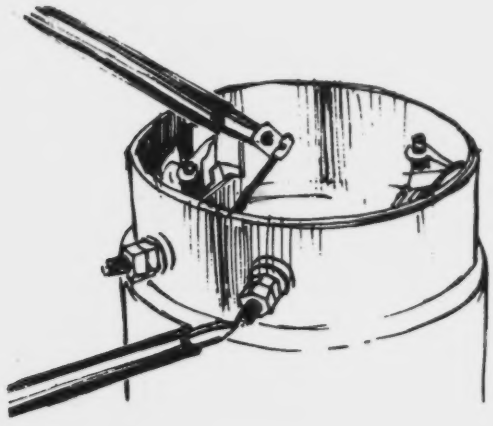
8. Test field coil for open circuit (Figure 112)

   a. Place one test lamp lead on field terminal

   b. Place other lead on end of field-coil lead through armature terminal

   (NOTE: If lamp does not light, the fields are open and must be replaced.)

FIGURE 112



9. Test field coil for ground on "A" circuit only (See Figure 113)

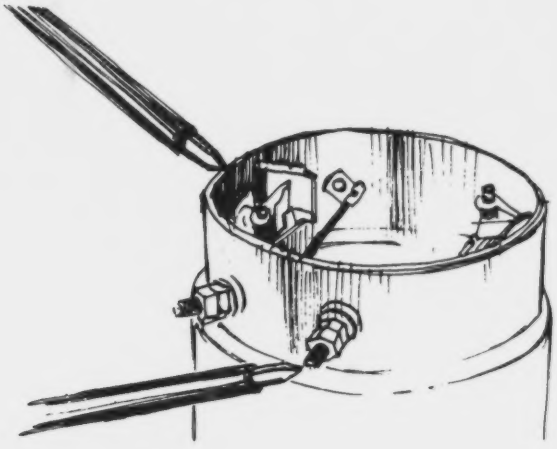
   a. Place one test lamp lead on generator housing ground

JOB SHEET #22

b. Place other lead on field terminal (Figure 113)

(NOTE: If lamp lights, the field coils are grounded and must be repaired or replaced.)

FIGURE 113



10. Check insulated brush holder for ground (See Figure 114)

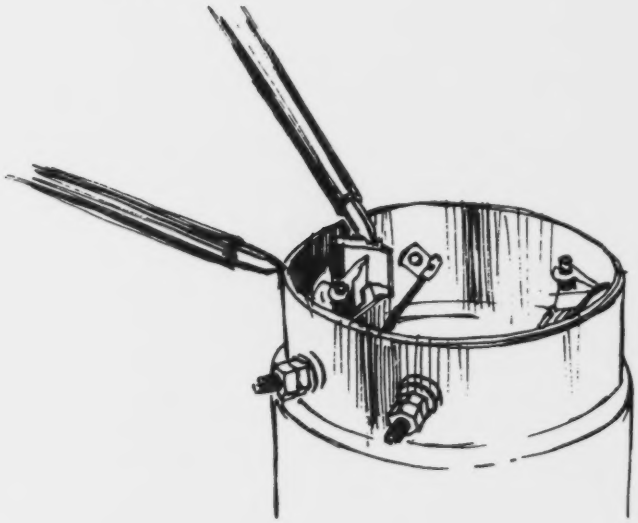
a. Place one test lamp lead on brush holder

JOB SHEET #22

b. Place other lead on generator housing (Figure 114)

(NOTE: If lamp lights, the insulated brush is grounded and must be repaired.)

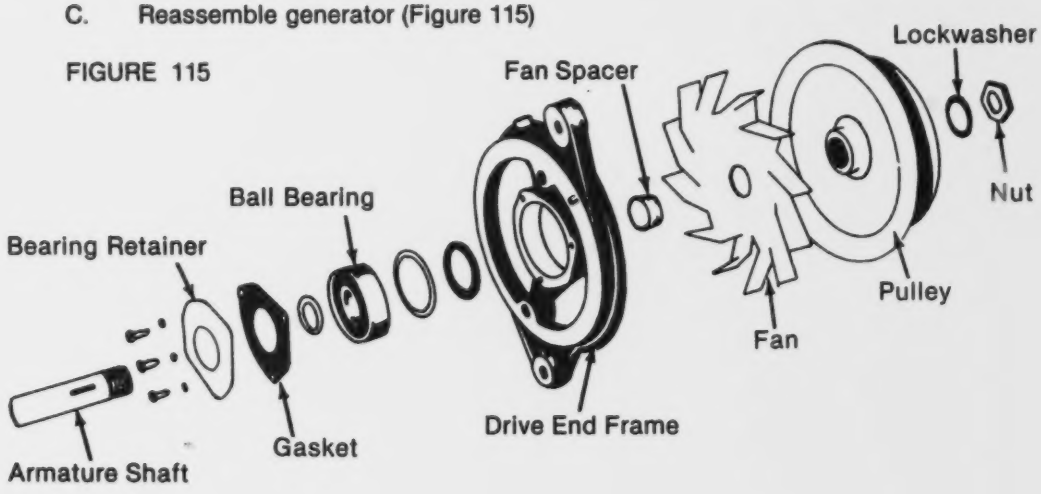
FIGURE 114



(NOTE: After all parts have been inspected, and all worn or damaged parts have been repaired or replaced, the generator is ready for assembly.)

C. Reassemble generator (Figure 115)

FIGURE 115



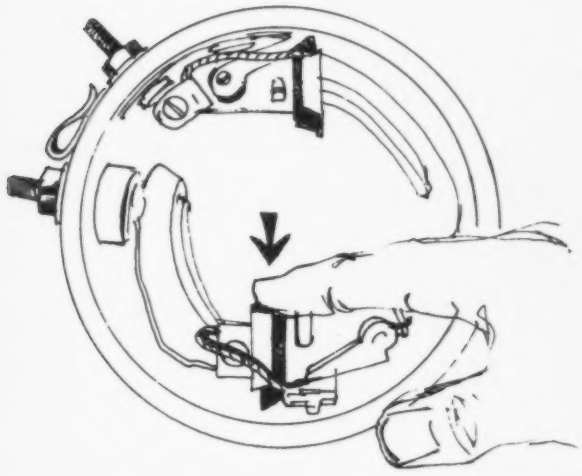
JOB SHEET #22

1. Pack generator ball bearing with high-melting-point bearing grease
2. Install ball bearing in drive end frame

   (NOTE: Make sure that gasket is in place and retainer screws are tightened securely.)
3. Install drive end frame and bearing assembly onto armature shaft

   (NOTE: If ball bearing spacer is used, make sure that it is in place.)
4. Install fan spacer, fan, pulley, and retaining nut
5. Tighten retaining nut securely
6. Install new brushes in brush holders, and push brushes back against spring tension (Figure 116)

FIGURE 116



7. Install armature and drive end-frame assembly into generator housing
8. Release brushes so that they will contact commutator
9. Assemble commutator end frame over end of armature shaft
10. Rotate both end frames until dowels engage; start through bolts
11. Tighten through bolts securely
12. Check generator operation before reinstalling generator on vehicle

D. Clean work area; clean and put away all tools and equipment

ELECTRICAL SYSTEMS
UNIT V

JOB SHEET #23 — REMOVE AND REPLACE AN ALTERNATOR

I. Equipment and materials

A. Vehicle

B. Basic hand-tool set

C. Belt tension gauge

D. Battery-cable clamp removal tool

E. Pliers

F. Safety glasses

G. Appropriate service manual

II. Procedure

A. Remove battery ground cable

(NOTE: The battery lead on the alternator will be dangerous to remove unless the battery ground cable has been removed from the battery.)

B. Remove wire leads from alternator

C. Remove alternator belt adjusting bolt

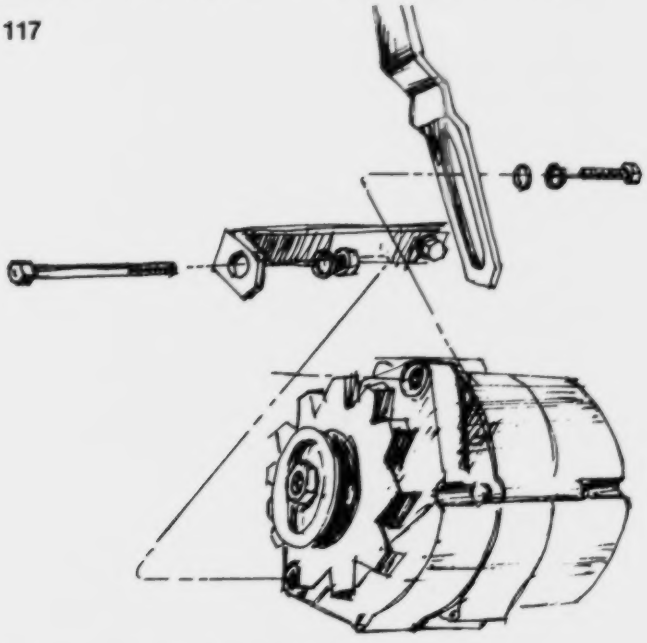
D. Move alternator toward engine

E. Remove alternator belt from alternator pulley

JOB SHEET #23

F. Remove bolts holding alternator to engine mounting bracket (Figure 117)

FIGURE 117



G. Lift alternator out of bracket

H. Service alternator as required

I. Position alternator in engine mounting bracket

J. Start alternator retaining bolts and tighten securely

K. Position alternator belt on pulley and move alternator away from engine to tighten belt

L. Pry alternator away from engine to adjust alternator-belt tension

(NOTE: Use caution when adjusting the alternator belt to avoid damaging the alternator. Refer to manufacturer's specifications for tightening procedures.)

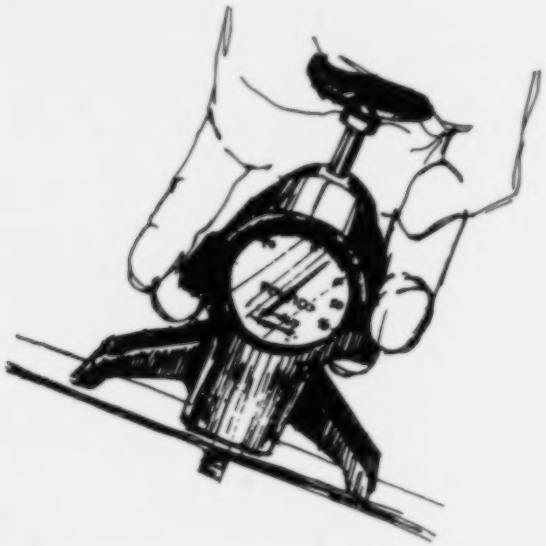
M. Install alternator adjusting bolt

JOB SHEET #23

N. Check alternator-belt tension with a belt-tension gauge and adjust to manufacturer's specifications (Figure 118)

(NOTE: The alternator belt must be adjusted properly so that it will keep the battery in a charged condition.)

FIGURE 118



O. Reinstall wire leads that were removed from the alternator; tighten securely

P. Reinstall battery ground cable

(CAUTION: Never attempt to polarize an alternator.)

Q. Clean work area; clean and put away all tools and equipment

ELECTRICAL SYSTEMS
UNIT V

JOB SHEET #24 — DISASSEMBLE, CHECK, AND REASSEMBLE AN ALTERNATOR

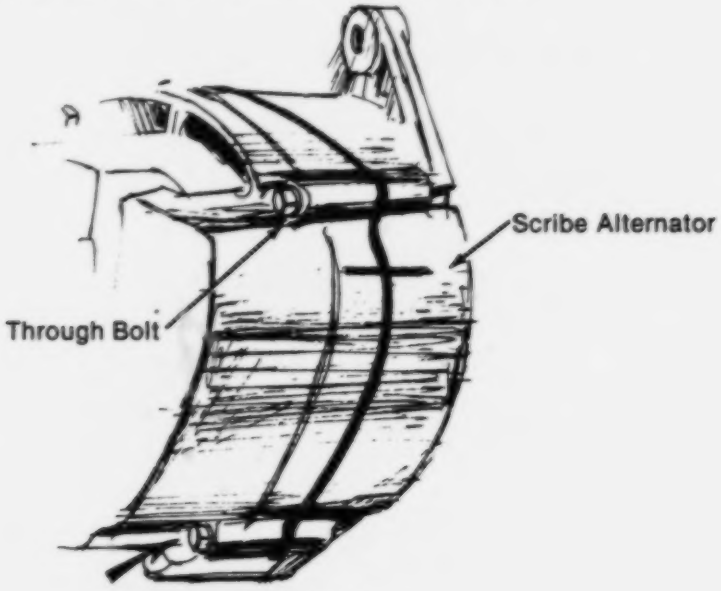
I. Equipment and materials

- A. Alternator, removed from vehicle
- B. Basic hand-tool set
- C. Alternator pulley removal tools
- D. Alternator diode removal equipment
- E. Alternator testing equipment
- F. Torque wrench
- G. Safety glasses
- H. Twelve-volt battery
- I. Appropriate service manual

II. Procedure

- A. Disassemble alternator
  1. Scribe alternator before disassembly (Figure 119)

FIGURE 119

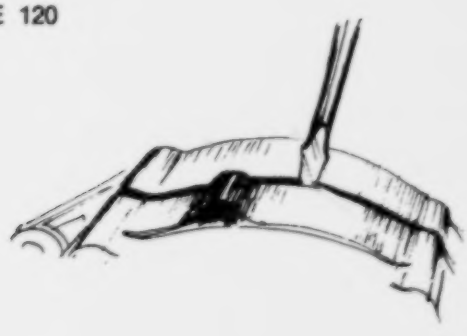


JOB SHEET #24

2. Remove through bolts holding end frames together

3. Pry at bolt locations to separate drive end frame from slip-ring end frame (Figure 120)

FIGURE 120



4. Remove slip-ring end frame and stator (as an assembly) from drive end frame and rotor assembly

5. Remove the three stator lead attaching nuts

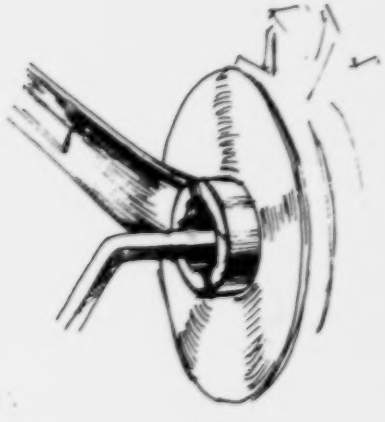
6. Separate stator from slip-ring end frame

7. Remove screws, brushes, and brush-holder assembly

8. Remove heat sink from end frame

9. Remove pulley retaining nut (Figure 121)

FIGURE 121



JOB SHEET #24

10. Remove pulley and fan, using pullers as required

11. Remove rotor and spacers from end-frame assembly

12. Remove drive end-frame bearing retainer and bearing from drive end frame

B. Clean and inspect alternator

1. Wash all metal parts except stator and rotor assemblies

2. Clean bearing and inspect for pitting or roughness

(NOTE: Replace bearing if required.)

3. Inspect rotor slip rings

(NOTE: The slip rings should be clean and free of scratches; service as required.)

4. Inspect brushes for wear

(NOTE: Replace brushes if required.)

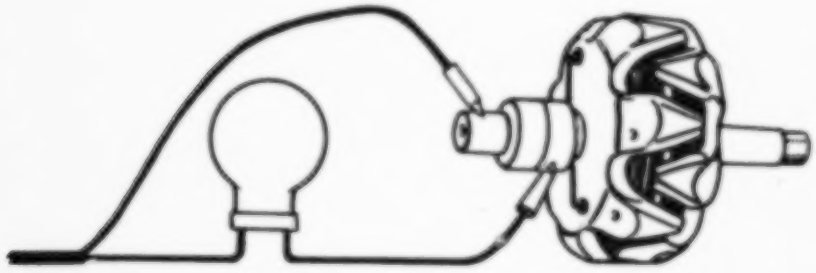
5. Test rotor for grounds (Figure 122)

a. Connect one test lamp lead to slip ring

b. Connect other test lamp lead to rotor shaft

(NOTE: If test lamp lights, the rotor is grounded.)

FIGURE 122



Used with permission of Standard Motor Products, Inc.

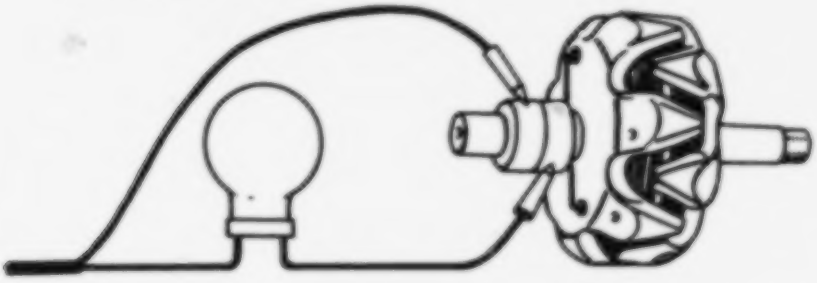
6. Test rotor for open circuit (Figure 123)

   a. Connect one test lamp lead to one slip ring

   b. Connect other lead to remaining slip ring

   (NOTE: If the test lamp does not light, the circuit is open.)

FIGURE 123



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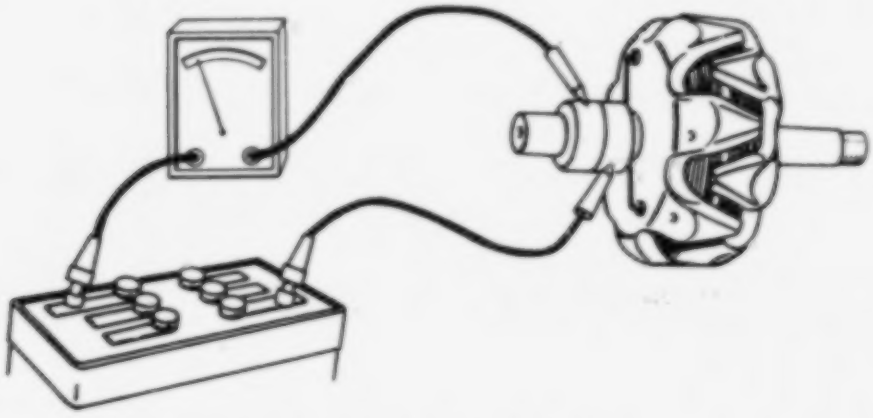
7. Test rotor for short circuit by connecting a 12-volt battery and ammeter in series with the two slip rings (Figure 124)

   (NOTE: An ammeter reading above specified field-amperage draw indicates a short circuit. Refer to manufacturer's specifications.)

FIGURE 124



Used with permission of Standard Motor Products, Inc.

JOB SHEET #24

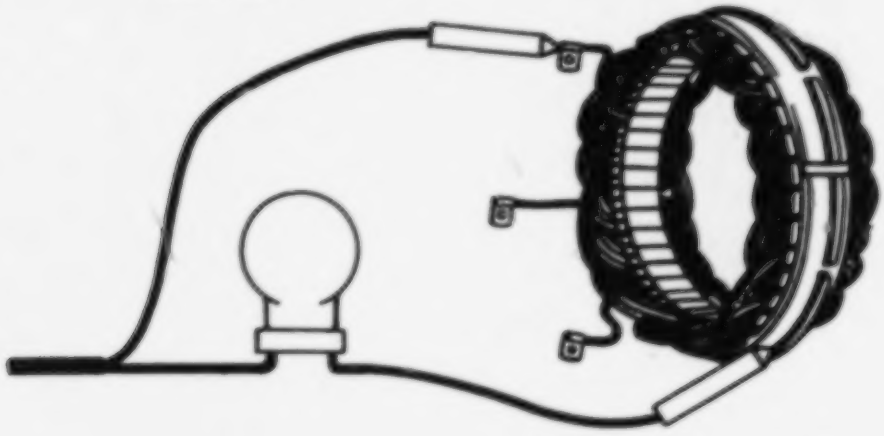
8. Test stator for grounds (Figure 125)

   a. Connect one test lamp lead to stator frame

   b. Connect other lead to any stator lead

   (NOTE: If the lamp lights, the windings are grounded.)

FIGURE 125



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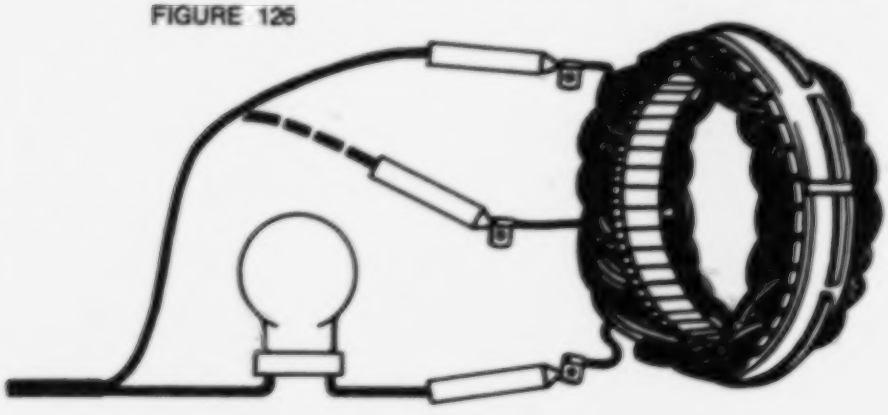
9. Test stator for open circuit by connecting a test lamp between each pair of stator leads (Figure 126)

   (NOTE: If test lamp fails to light, the stator windings are open.)

FIGURE 126



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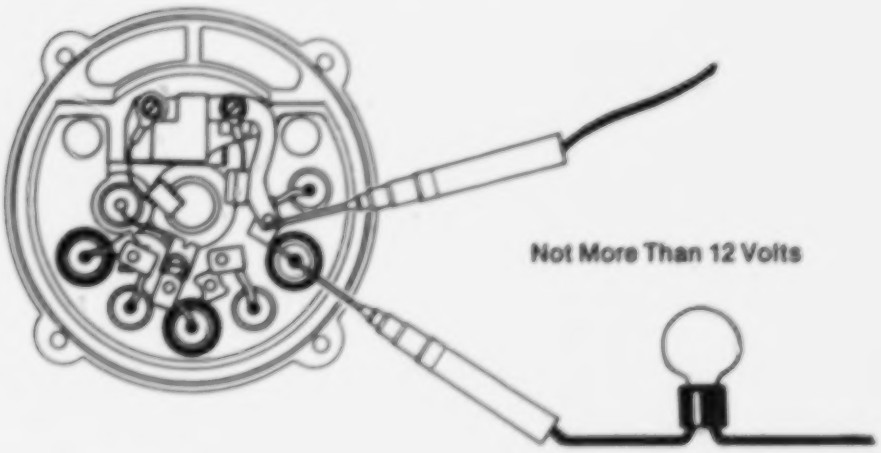
JOB SHEET #24

10. Test diodes with an ohmmeter or a test lamp of not more than 12 volts (Figure 127)

FIGURE 127



Used with permission of Standard Motor Products, Inc.

11. Test heat-sink diodes

    a. Connect one lead of a 12-volt test lamp to heat sink

    b. Connect other test lamp lead to diode lead

    (NOTE: If the lamp lights in both directions, or fails to light at all, the diode is defective.)

12. Test end-frame diodes

    a. Connect one lead of a 12-volt test lamp to end frame

    b. Connect other test lamp lead to diode lead

    (NOTE: If lamp lights in both directions, or fails to light at all, the diode is defective.)

13. Replace any parts found defective

14. Replace any diodes found defective

(NOTE: Use proper diode removal and replacement tools.)

JOB SHEET #24

15. Replace slip-ring end-frame bearing assembly if grease supply is exhausted

    (NOTE: Make no attempt to relubricate or reuse bearings.)

16. Repack drive end bearings with proper lubricant

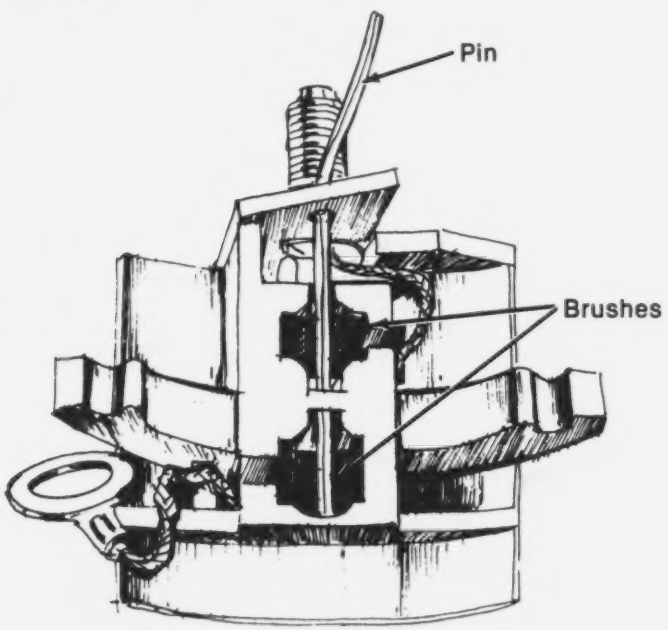
C. Reassemble alternator

1. Assemble heat sink to end frame

2. Install brush holder and brushes into slip-ring end frame

   (NOTE: Insert a pin or wire through the hole to hold the brushes in the holder; see Figure 128.)

   FIGURE 128



3. Reinstall stator assembly in slip-ring end frame, locating diode connectors over the relay, diode, and stator leads

4. Reinstall and tighten terminal nuts securely

5. Reinstall bearing in drive end frame

JOB SHEET #24

6. Reinstall rotor in drive end frame

7. Reinstall fan, spacer, pulley, and retaining nut

8. Tighten nut to manufacturer's specifications

9. Reassemble slip-ring end frame and stator assembly to drive end frame and rotor assembly

   (NOTE: Align end frames by referring to scribe marks put on during disassembly.)

10. Reinstall through bolts in end-frame assembly

11. Tighten bolts securely

12. Remove pin holding brushes in place

D. Clean work area; clean and put away all tools and equipment

ELECTRICAL SYSTEMS
UNIT V

JOB SHEET #25 — TEST ALTERNATOR CHARGING-CIRCUIT RESISTANCE

I. Equipment and materials

A. Vehicle

B. DC volt-ammeter

C. Carbon-pile rheostat

D. Battery cable puller

E. Basic hand-tool set

F. Safety glasses

G. Jumper wire

H. Appropriate service manual

II. Procedure

(NOTE: The charging-system circuit resistance test will show the amount of voltage drop between the alternator output terminal and the battery.)

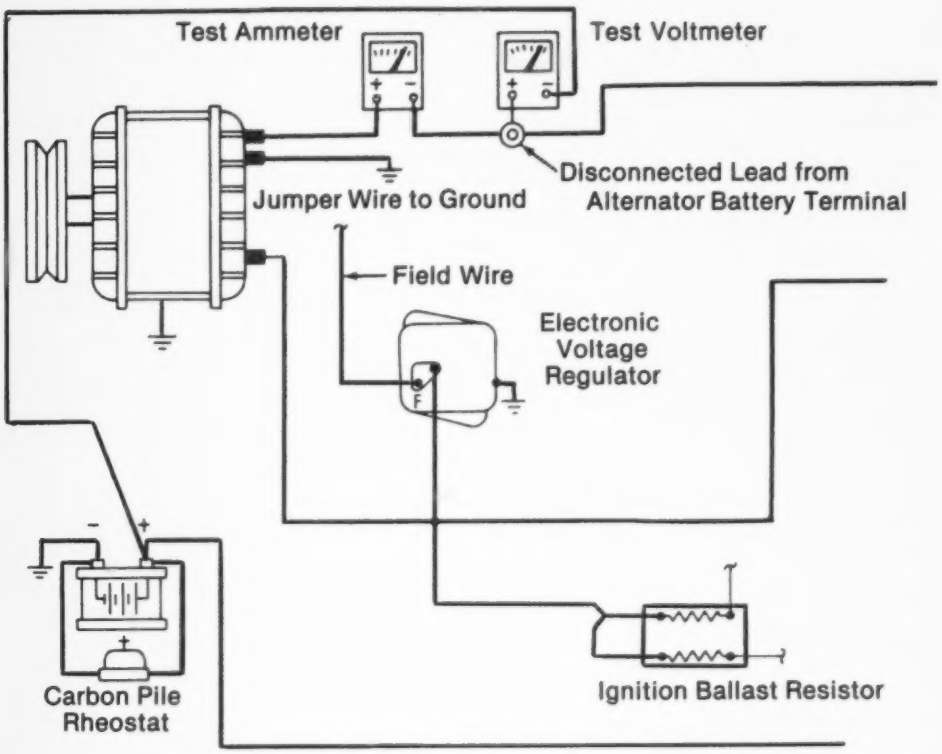
A. Remove battery ground cable

B. Disconnect BAT lead at alternator output terminal

C. Connect ammeter in series between alternator BAT terminal and disconnected BAT lead wire (See Figure 129)

D. Connect positive lead of voltmeter to disconnected BAT lead wire (Figure 129)

FIGURE 129



E. Connect negative lead of voltmeter to battery positive post (See Figure 130)

JOB SHEET #25

F. Apply battery voltage to alternator field (Figure 130)

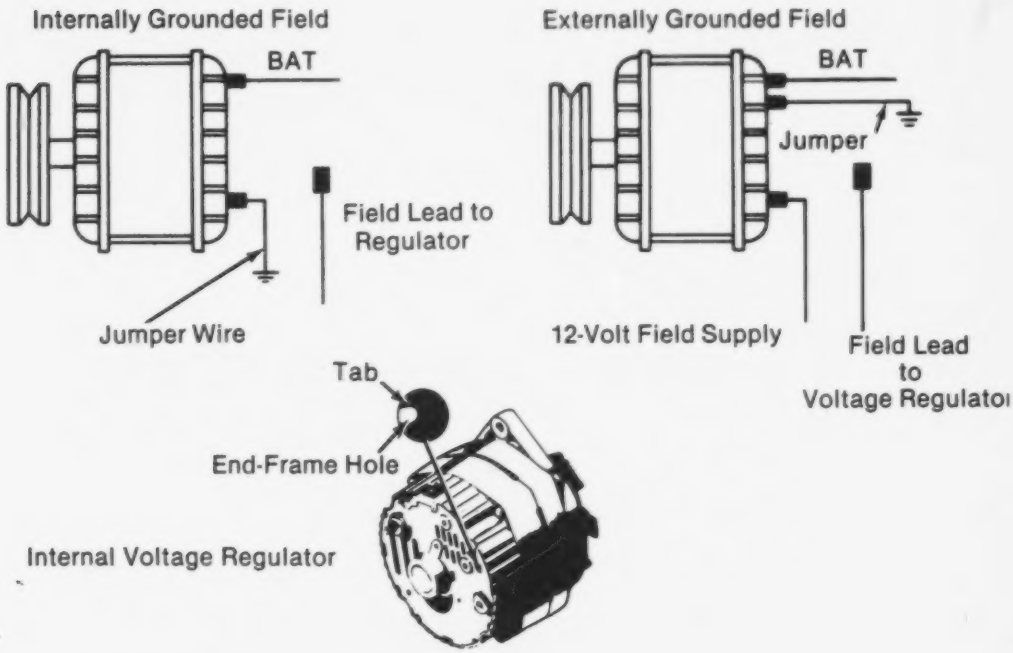
1. Disconnect field lead from alternator and connect a jumper from field terminal to BAT terminal on internally grounded fields

2. Disconnect field grounding lead and connect a jumper from that terminal to ground on externally grounded fields

3. On internally mounted voltage regulator, ground voltage-regulator tab by inserting a screwdriver through the D-shaped hole in the rectifier end frame of the alternator

(NOTE: Consult the appropriate service manual to determine the type of system you have.)

FIGURE 130



G. Reconnect battery ground cable

H. Connect variable carbon-pile rheostat to battery

(CAUTION: Be sure that carbon-pile rheostat is in the OPEN or OFF position before connecting the leads to the battery.)

JOB SHEET #25

I. Start engine and operate at idle speed only

J. Adjust engine speed and carbon-pile rheostat to maintain 20 amperes flowing in circuit

K. Observe voltmeter reading

(NOTE: The voltmeter reading should not exceed 0.7 volts. If higher voltage drop is indicated, inspect, clean, and tighten all connections in the charging circuit. A voltage-drop test may be performed at each connection to locate the one with excessive resistance.)

L. Turn off carbon-pile rheostat

M. Shut off engine

N. Remove ground battery cable

O. Remove test equipment from vehicle

P. Reconnect all alternator wires to their proper terminals

Q. Reconnect ground battery cable after making necessary repairs

R. Clean work area; clean and put away all tools and equipment

ELECTRICAL SYSTEMS
UNIT V

JOB SHEET #26 — TEST ALTERNATOR CURRENT OUTPUT

I. Equipment and materials

A. Vehicle

B. DC volt-ammeter

C. Basic hand-tool set

D. Safety glasses

E. Carbon-pile rheostat

F. Jumper wire

G. Engine tachometer

H. Appropriate service manual

II. Procedure

(NOTE: The current-output test determines whether or not the alternator is capable of delivering its rated current output.)

A. Disconnect battery ground cable

B. Disconnect BAT lead wire at alternator output terminal

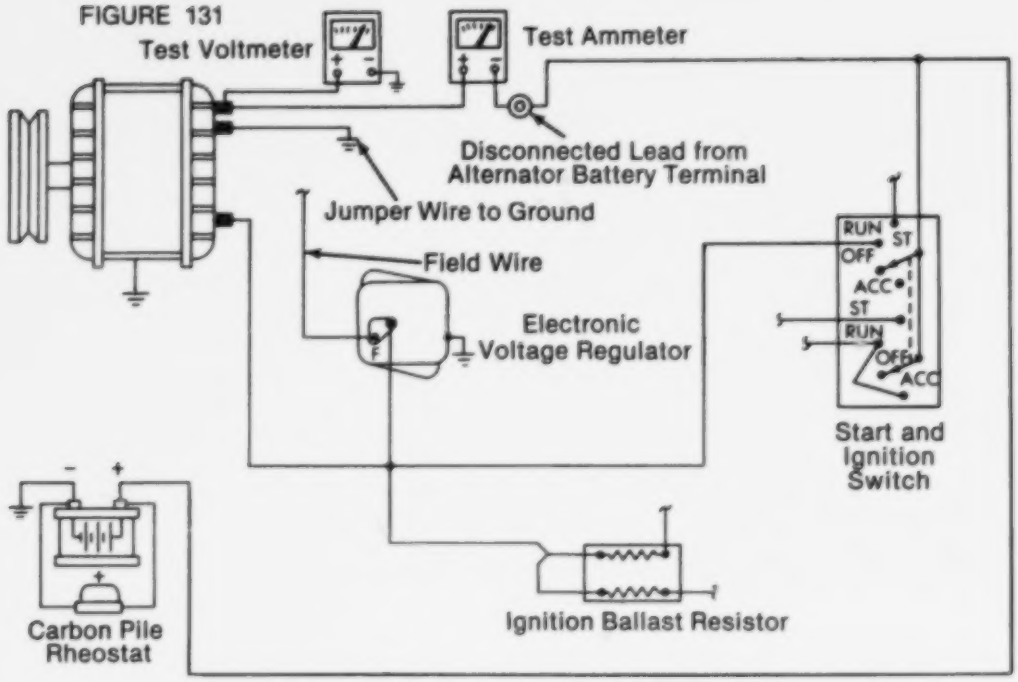
C. Connect ammeter in series between alternator BAT terminal and disconnected lead wire (See Figure 131)

D. Connect positive lead of voltmeter to BAT terminal of alternator (See Figure 131)

JOB SHEET #26

E. Connect negative lead of voltmeter to a good ground (Figure 131)

FIGURE 131



F. Apply battery voltage to alternator field (Figure 132)

(NOTE: Consult the appropriate service manual to determine the type of system you have.)

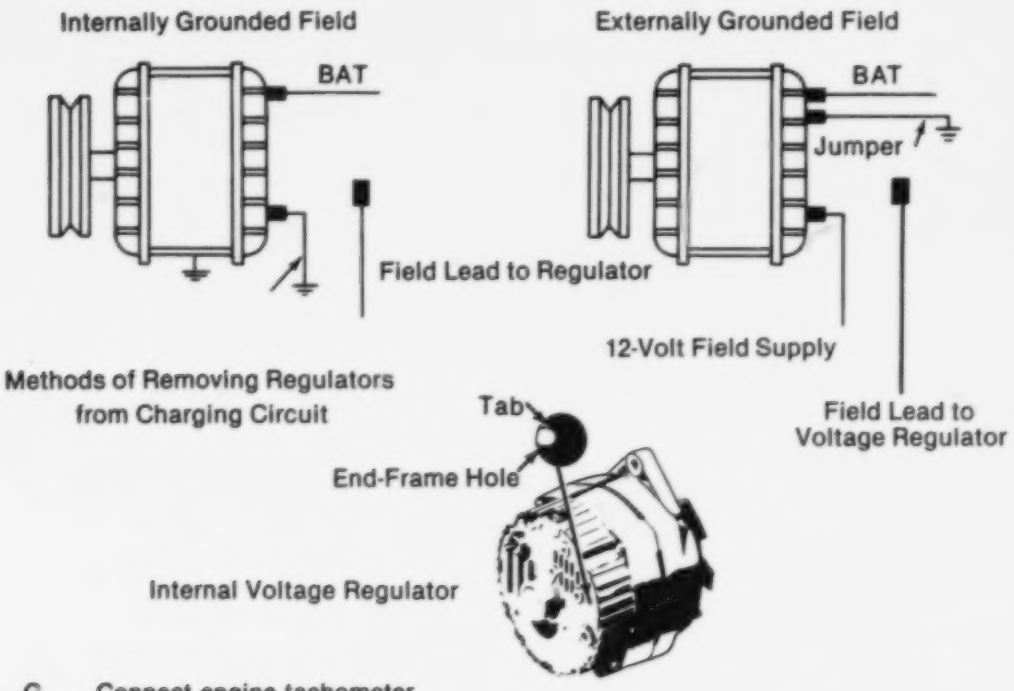
1. Disconnect field lead from alternator, and connect a jumper wire from field terminal to BAT terminal on internally grounded fields (See Figure 132)

2. Disconnect field grounding lead and connect a jumper wire from that field terminal to a good ground on externally grounded fields (See Figure 132)

JOB SHEET #26

3. On internally mounted regulators, ground voltage regulator tab by inserting a screwdriver through the O-shaped hole in rectifier end frame of alternator (Figure 132)

FIGURE 132



G. Connect engine tachometer

H. Reconnect battery ground cable

I. Connect variable carbon-pile rheostat between battery terminals

(NOTE: Refer to Figure 131.)

(CAUTION: Be sure that carbon-pile rheostat is in the OPEN or OFF position before reconnecting to the battery.)

J. Start engine and operate at idle speed

K. Adjust carbon-pile rheostat and engine speed in increments until a speed of 1,250 revolutions per minute and a voltmeter reading of 15 volts is obtained

(NOTE: These specifications may vary slightly from model to model, so consult the appropriate service manual for accurate specifications.)

(CAUTION: Never allow voltmeter to read over 16 volts; damage to the charging system could occur.)

JOB SHEET #26

L. Read ammeter

(NOTE: The ammeter reading should be within the limits of rated output for the particular alternator being tested.)

M. Remove alternator for bench testing if readings are less than specified

(NOTE: Some models have a field-load relay that should be tested for proper operation before removing the alternator.)

N. Reduce engine speed and turn off carbon-pile rheostat after current-output test is completed

O. Turn off ignition switch

P. Remove battery ground cable

Q. Remove test equipment and jumper wire

R. Reconnect field lead wire and ground battery cable

S. Clean work area; clean and put away all tools and equipment

ELECTRICAL SYSTEMS
UNIT V

JOB SHEET #27 — TEST EXTERNAL-TYPE VOLTAGE REGULATOR

I. Equipment and materials

A. Vehicle

B. DC volt-ammeter

C. Basic hand-tool set

D. Safety glasses

E. Wire brush

F. Battery-post and cable-clamp brush

G. Belt tension gauge

H. Appropriate service manual

II. Procedure

A. Clean battery terminals

B. Check specific gravity of battery electrolyte

(NOTE: Specific gravity should be above 1.200 to allow a proper regulator check.)

C. Check alternator drive-belt tension and adjust as necessary

D. Connect voltmeter positive lead to battery positive post

E. Connect voltmeter negative lead to a good ground

F. Start engine and operate at approximately 1,250 revolutions per minute with lights and accessories turned off

G. Check voltmeter reading

(NOTE: The regulator is working properly if the voltage readings are in accordance with manufacturer's specifications.)

III. Test results

A. Fluctuating or below-limits voltage

1. Check for good grounding of voltage regulator

JOB SHEET #27

2. Test supply circuit to voltage regulator

   (NOTE: Supply circuit should equal battery voltage.)

3. Test field-circuit voltage

   (NOTE: Voltage through the field circuit, field wires, brushes, and rotor should be equal to battery voltage.)

4. Replace voltage regulator if tests A1, A2, and A3 are satisfactory

B. Voltage above the specified limits

1. Check supply circuit to voltage regulator

   (NOTE: Supply current should equal battery voltage.)

2. Check field voltage

   (NOTE: Field-circuit voltage should equal battery voltage.)

3. Replace voltage regulator if steps B1 and B2 are satisfactory

   (NOTE: On models using a field relay, test relay for proper operation before replacing the voltage regulator.)

C. Clean work area; clean and put away all tools and equipment

ELECTRICAL SYSTEMS
UNIT V

JOB SHEET #28 — TEST INTERNAL-TYPE VOLTAGE REGULATOR ON VEHICLE

I. Tools and equipment

- A. Vehicle
- B. DC volt-ammeter
- C. Basic hand-tool set
- D. Carbon-pile rheostat
- E. Engine tachometer
- F. Wire brush
- G. Battery-post and cable-clamp brush
- H. Belt tension gauge
- I. Appropriate service manual

II. Procedure

- A. Clean battery terminals
- B. Check battery specific gravity

  (NOTE: Specific gravity should be above 1.200 to allow proper regulator checks.)

- C. Check alternator drive-belt tension and adjust as necessary
- D. Check all charging-system wiring for defects and all terminal connections for cleanliness and tightness

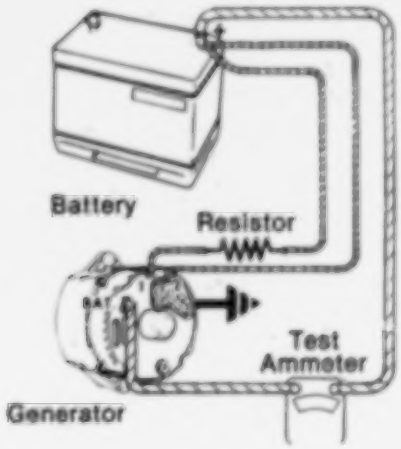
  (NOTE: If all the above steps are satisfactory, check the alternator with the following procedure.)

- E. Disconnect battery ground cable

JOB SHEET #28

F. Connect an ammeter in series at BAT terminal of alternator (Figure 133)

FIGURE 133

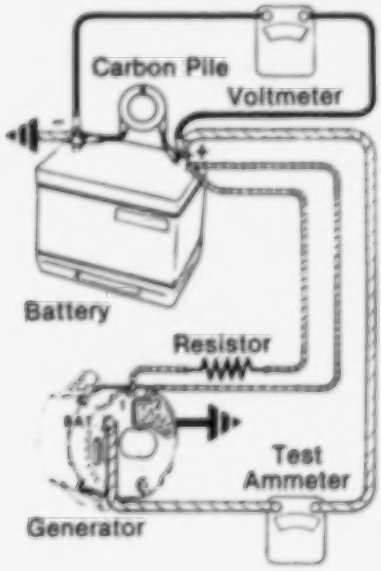


G. Reconnect battery ground cable

H. Turn on radio, windshield wipers, lights at high beam, and blower motor at high speed

I. Connect a carbon-pile rheostat across battery (Figure 134)

FIGURE 134



JOB SHEET #28

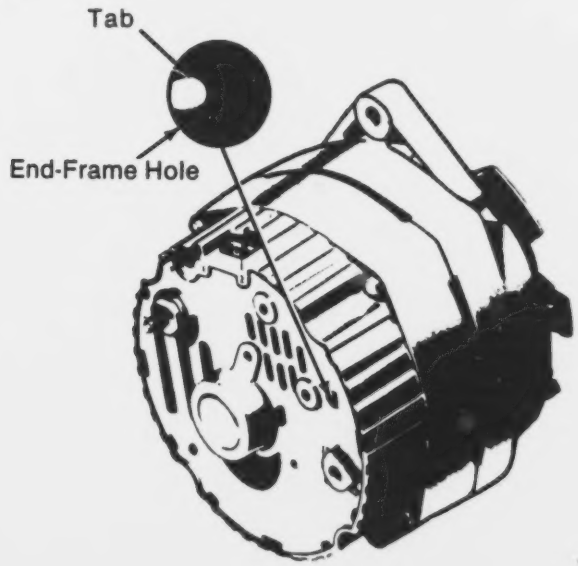
J. Operate engine at moderate speed and adjust carbon-pile rheostat as required to obtain maximum current output

(NOTE: If ampere output is within 10 percent of rated output, the alternator and regulator are not defective.)

K. If ampere output is not within 10 percent of rated output, ground alternator-field winding tab by inserting a screwdriver in the test hole on rectifier end frame (Figure 135)

(CAUTION: Tab is within 3/4 inch of the casting surface. Do not force screwdriver deeper into the end frame; severe damage to the alternator could result.)

FIGURE 135



L. Operate engine at moderate speed, and adjust carbon-pile rheostat to obtain maximum current output

(NOTE: If current output is within 10 percent of rated output, replace the voltage regulator. If current output is not within 10 percent of rated output, remove alternator and bench-test field windings, rectifier, and stator.)

M. Clean work area; clean and put away all tools and equipment

ELECTRICAL SYSTEMS
UNIT V

TEST

NAME _____ SCORE _____

1. Match to their correct definitions terms associated with electrical systems. Write the correct numbers in the blanks. Terms and definitions are continued on the following page.

_____a.	Property of a conductor by which it opposes the flow of an electric current, resulting in generation of heat in conducting material	1. Joule (J)
_____b.	Standard unit for measuring the strength of an electric current; rate of flow or charge in a conducting medium of 1 coulomb per second	2. Voltage (V)
_____c.	Newton unit of energy; amount of work done by 1 newton acting through a distance of 1 meter and equal to 10,000 ergs	3. Insulator
_____d.	Flow of electrons in a conductor that reverses direction of flow at intervals	4. Ampere (A)
_____e.	Unit of force in the meter-kilogram-second (mks) system	5. Newton (N)
_____f.	Force that tends to cause a flow of electricity that is measured in volts	6. Resistance (R)
_____g.	Any material that allows electrical current to flow through it easily	7. Current (I)
_____h.	Material that resists the flow of electrical current	8. Alternating current (AC)
_____i.	Flow of electrons measured in amperes; flow of electrical charge	9. Conductor
_____j.	Unit of potential difference of electromotive force equal to the potential difference between two points for which 1 coulomb of electricity will do 1 joule of work in going from one point to another	10. Volt (V)
_____k.	Potential difference or electromotive force measured in volts	11. Electromotive force (emf)

TEST

_____l. Steady flow of electrons moving continually in the same direction along a conductor from a point of high potential to one of lower potential

_____m. Unit of electrical resistance equal to the resistance through which a current of 1 ampere will flow when there is a potential difference of 1 volt across it

_____n. Number of degrees of distributor-cam rotation that the ignition points are closed

_____o. Charge transported through a conductor by a current of 1 ampere flowing for one second; legal standard of electricity

_____p. System that uses a control unit and magnetic pickup to open and close the primary circuit

_____q. Collective term applied to the positive and negative ends of a magnet or the direction of current flow in a circuit

_____r. Object that converts electrical energy into heat, light, or mechanical energy

_____s. Continuous path along a conductor through which electrical current can flow from a source, through a load, and back to the source

12. Ohm (Ω)
13. Direct current (DC)
14. Electronic ignition system
15. Load (L)
16. Polarity
17. Dwell
18. Coulomb (coul)
19. Circuit

2. List basic factors of electrical flow in a circuit.

   a. _____

   b. _____

   c. _____

3. Discuss relationship of voltage, amperage, and ohms to current flow.

   a. Voltage — _____

   _____

TEST

b. Amperage — _____

_____

c. Ohms — _____

_____

4. Select from the following list factors that affect resistance in a conductor. Write an "X" in the blank before each correct answer.

_____a. Cross section (size of conductor)

_____b. Size

_____c. Temperature

_____d. Material

_____e. Source

_____f. Length

5. List components of a basic electrical circuit.

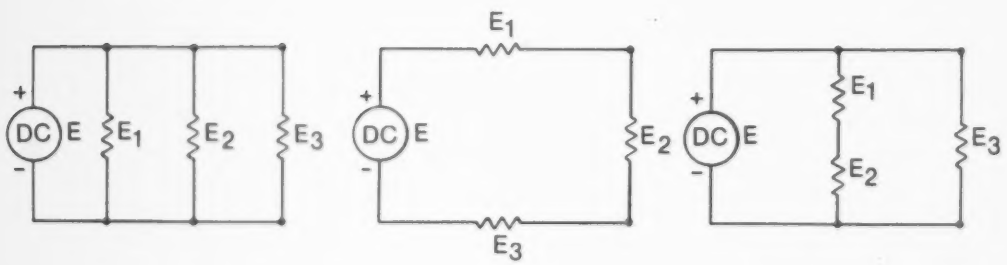
a. _____

b. _____

c. _____

d. _____

6. Label the following types of electrical circuits. Write the correct names in the blanks.



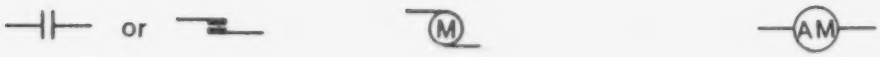
a. _____ b. _____ c. _____

TEST

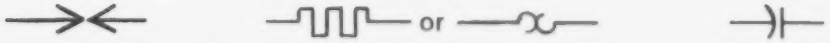
7. Identify the following basic symbols used in electrical systems. Write the correct names in the blanks.

Battery	**Positive terminal**	**Lamp**	**Fusible link or wire**
Ground	**Negative terminal**	**Fuse**	**Condenser (capacitor)**
Voltmeter	**Fixed resistor**	**Coil**	**Diode (one-way)**
Ammeter	**Inductor**	**Ohm**	**Variable resistor**
Alternator	**Spark gap**	**Motor (DC)**	**Contact points**
Transistor	**Circuit breaker**	**Switch (open)**	**Switch (closed)**
Zener diode	**Thermal element**		

a. _____ b. _____ c. _____



d. _____ e. _____ f. _____



g. _____ h. _____ i. _____

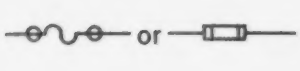
j. _____ k. _____ l. _____

m. _____ n. _____ o. _____

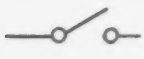
TEST

p. _____

q. _____



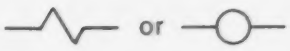
r. _____



s. _____

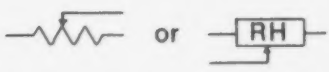
Ω

t. _____



u. _____

v. _____



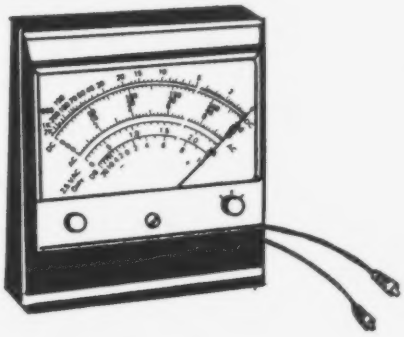
w. _____

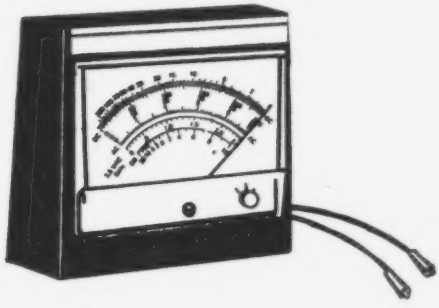
x. _____

y. _____ z. _____

8. Identify the following instruments used to test electrical circuits. Write the correct names in the blanks.

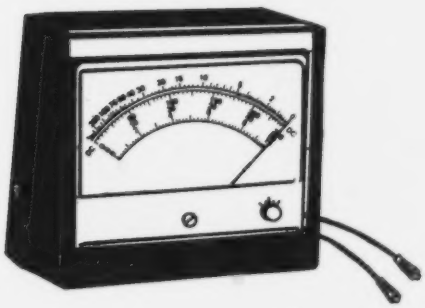
Ammeter **Voltmeter** **Ohmmeter**





a. _____ b. _____

TEST



c. _____

9. Distinguish between direct current and alternating current. Write an "X" in the blank pertaining to alternating current.

_____a. Flows in one direction; then reverses and flows in opposite direction

_____b. Flows in one direction only

10. State functions of the battery.

a. _____

b. _____

c. _____

11. State two processes by which a battery converts chemical energy into electrical energy.

a. _____

_____

b. _____

_____

TEST

12. Match types of battery ratings to their correct descriptions. Write the correct numbers in the blanks.

_____a.	Length of time in minutes that a fully charged battery at 80°F (26.7°C) can deliver a specified quantity of current	1. Cold-cranking rating
_____b.	Number of amperes that a battery can deliver for thirty seconds at 0°F (17.8°C) without the cell voltage dropping below 1.2 volts	2. Peak watt rating (PWR)
_____c.	Measure of the battery's cold-cranking ability determined by multiplying the maximum current by the maximum voltage the battery is capable of producing	3. Ampere/hour rating (reserve capacity rating)

13. Select from the following list safety rules pertaining to care and maintenance of batteries. Write an "X" in the blank before each correct answer.

_____a. Keep flames and sparks away from battery because gases given off by battery are very explosive

_____b. Flush immediately with water any area of skin that acid has contacted

_____c. Do not allow battery electrolyte to come into contact with clothing, skin, eyes, or painted surfaces

_____d. Breathe fumes from battery that is being charged

_____e. Avoid shorting or grounding battery terminals during service

_____f. Wear safety goggles, rubber gloves, and rubber apron when servicing battery

14. Match terms associated with starting systems to their correct definitions. Write the correct numbers in the blanks. Terms and definitions are continued on the following page.

_____a.	Housing for starter and mounting for field coils and pole shoes	1. Brush
_____b.	Sliding contact used to pass electrical current to a rotating armature	2. Commutator
_____c.	Device for reversing the direction of current flowing through the conductors of the rotating armature in a motor	3. Frame

TEST

_____d.	Coil or winding in a generator or starter; produces a magnetic field as current passes through it	4. Pole shoe 5. Field coil
_____e.	Solid or laminated metal core inside a field coil; used to concentrate the magnetic lines of force to produce a strong magnet	6. Armature 7. Solenoid
_____f.	Tubular field coil with a movable metal core used to engage the starter drive with the flywheel and to close the starter switch	8. Starter drive
_____g.	Series of loops of wire arranged around a shaft and made to rotate due to magnetic action	
_____h.	Device used to transmit power produced in starter to engine	

15. State the purpose of the starting system.

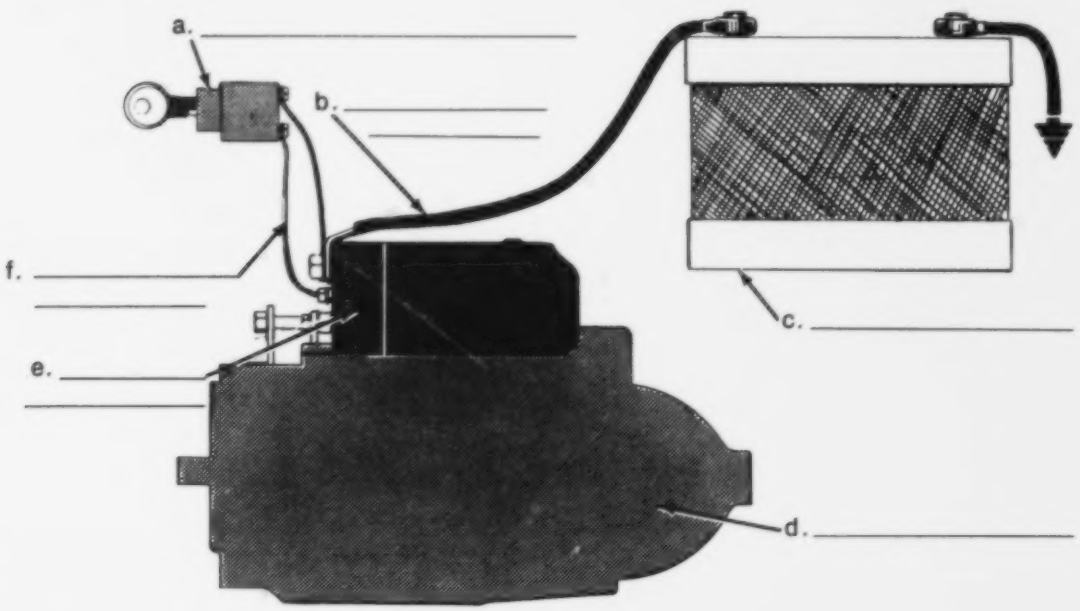
_____

_____

_____

TEST

16. Label components of the starting system illustrated below. Write the correct names in the blanks.



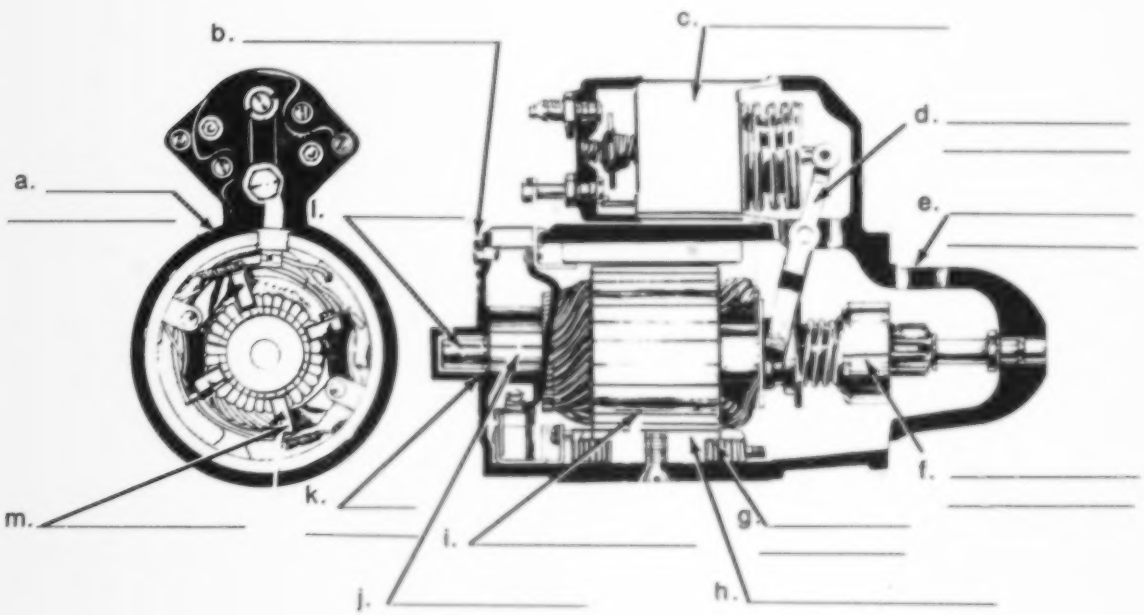
17. Match major parts of a starting circuit to their correct functions. Write the correct numbers in the blanks.

_____a.	Supplies energy for the circuit	1. Starter switch
_____b.	Activates the circuit	2. Starting motor
_____c.	Closes circuit to motor and engages motor drive with flywheel	3. Battery
_____d.	Drives flywheel to start engine	4. Motor switch

TEST

18. Identify basic parts of a starter. Write the correct names in the blanks.

Through bolt	**Starter brush**	**Armature**	**Starter drive**
Shift lever	**End frame**	**Solenoid**	**Starter frame**
Drive housing	**Field coil**	**Bushing**	**Commutator**
Pole shoe			



19. State the purpose of the ignition system.

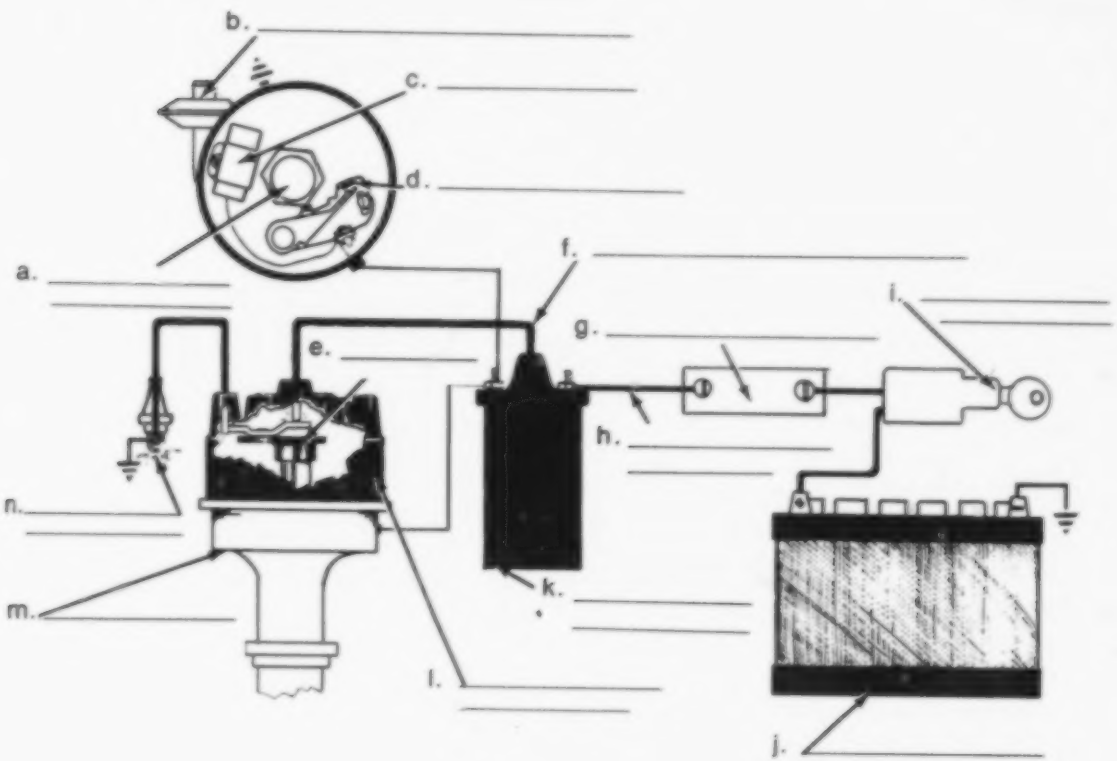
_____

_____

TEST

20. Identify components of the ignition system illustrated below. Write the correct names in the blanks.

Battery	**Primary resistance unit**	**Ignition switch**	**Ignition coil**
Rotor	**Spark-advance mechanism**	**Contact points**	**Breaker cam**
Condenser	**Secondary ignition cable**	**Spark plug**	**Distributor cap**
Distributor	**Primary ignition wire**		



TEST

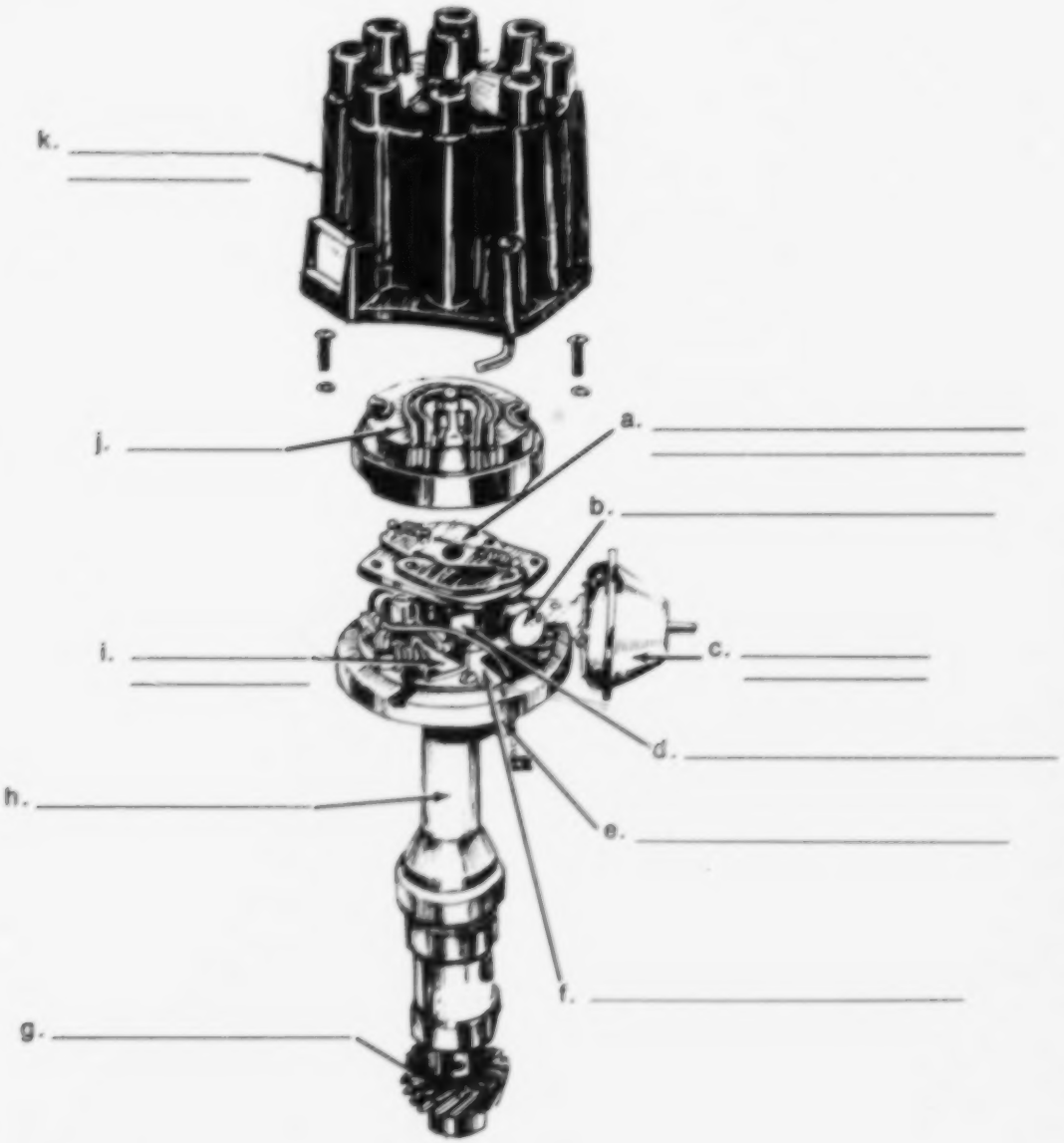
21. Match components of the ignition system to their correct functions. Write the correct numbers in the blanks.

_____a.	Reduces voltage in primary circuit to protect contact points	1. Spark-advance mechanism
_____b.	Opens and closes primary circuit from battery to coil	2. Ignition coil
_____c.	Carries high voltage from secondary winding of coil to spark plug (heavy insulated wire)	3. Distributor
_____d.	Transforms low voltage into high voltage necessary to jump the spark-plug gap	4. Battery
_____e.	Makes and breaks the primary circuit to allow coil to produce high voltage at the spark plugs	5. Condenser
_____f.	Stores extra current as the contact points open to prevent arcing and burning; aids coil primary winding to build up magnetic field by releasing its charge back into the circuit as the points close	6. Resistance unit
_____g.	Contains the contact points and condenser; distributes the high-voltage current from coil to proper cylinder	7. Breaker cam
_____h.	Opens and closes contact points	8. Contact point
_____i.	Regulates timing of high-voltage circuit for best ignition during all speed and load conditions	9. Ignition switch
_____j.	Takes high-voltage current from coil and directs it to correct cylinder	10. Primary ignition wire
_____k.	Holds coil and spark-plug wires in sequence and provides a cover for distributor	11. Distributor cap
_____l.	Provides a spark gap inside engine cylinder to ignite fuel/air mixture	12. Secondary ignition cable
_____m.	Carries low voltage from battery to primary winding of ignition coil (light wire)	13. Rotor
_____n.	Serves as a source of electrical power	14. Spark plug

TEST

22. Identify basic components of the distributor illustrated below. Write the correct names in the blanks.

Distributor cap	**Centrifugal advance mechanism**	**Breaker plate**
Distributor cam	**Vacuum advance unit**	**Contact points**
Distributor housing	**Distributor drive gear**	**Primary lead wire**
Rotor	**Condenser**	



TEST

23. Distinguish between the components of the primary and secondary ignition circuits. Write a "P" in the blanks before primary circuit and an "S" in the blanks before secondary circuit.

_____a. Low-voltage wire

_____b. Resistance unit

_____c. Rotor

_____d. Contact points

_____e. Spark plug

_____f. Secondary winding of the coil

_____g. Battery

_____h. Primary winding of the coil

_____i. Distributor cap

_____j. Ignition switch

_____k. High-voltage cable

_____l. Condenser

24. Arrange in order the steps of ignition-system operation through one complete cycle, beginning with the battery. Write a "1" in the blank before the first step, a "2" before the second step, and so on.

_____a. As contact points open, current continues to flow across the point surfaces; condenser attached to points absorbs this flow of current

_____b. The flow of low-voltage current through primary winding of coil causes a magnetic-field buildup

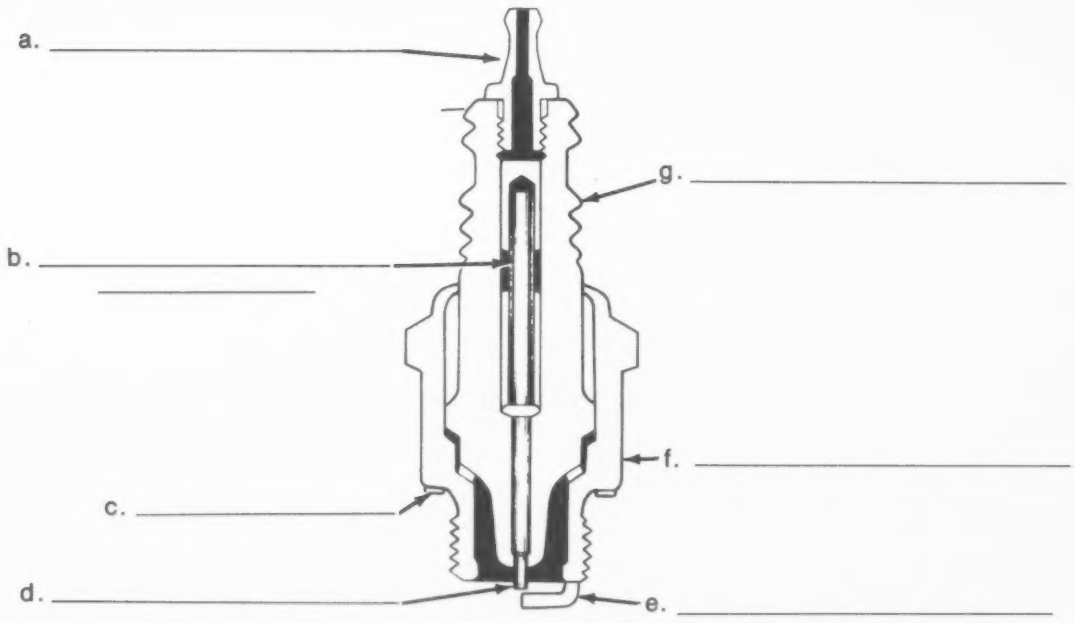
_____c. This high-voltage surge is directed from secondary winding of coil through distributor cap and rotor and on to spark plug to ground

_____d. With ignition switch on and contact points closed, low-voltage current flows from battery through primary winding of the coil and through contact points to ground

_____e. Stopping this flow of current causes magnetic field of coil primary winding to collapse across the secondary coil winding, causing a high-voltage surge

TEST

25. Label the parts of the spark plug illustrated below. Write the correct names in the blanks.



26. Match conditions of spark plugs to their correct causes. Write the correct numbers in the blanks. Causes are continued on the following page.

_____a. Powdery white or yellow deposits that build up on shell, insulator, and electrodes; this is a normal appearance with certain brands of fuels

_____b. Dry deposits indicate rich mixture or weak ignition

_____c. Spotted deposits occur shortly after long-delayed tune-up

_____d. Spark plug will not have deposits, but the porcelain will be white and blistered with center electrode eroded

_____e. Spark plug will have melted electrodes with center electrode generally melting first and ground electrode following

1. Too hot
2. Modifier deposits
3. Normal
4. High-speed glazing
5. Carbon deposits
6. Splashed deposits
7. Preignition
8. Oil deposits

TEST

_____f. Insulator has yellowish, varnishlike color indicating that combustion-chamber temperatures have risen suddenly during hard, fast acceleration

_____g. Insulator is brown to grayish tan with slight electrode wear

_____h. Condition is caused by poor oil control; oil is leaking past worn valve guides or piston rings into combustion chamber

27. Distinguish between transistorized and capacitive-discharge ignition systems. Write a "T" in the blanks before transistorized and a "C" in the blanks before capacitive discharge.

_____a. System contains special ignition distributor, amplifier, and coil

_____b. Transistors allow very low voltage through points and battery to primary winding in coil

_____c. Amplifier is included in circuit between points and ignition coil

_____d. System operates to charge a capacitor to a high voltage that, on signal from distributor, is then discharged through primary winding in coil

28. Discuss relationship of an electronic ignition system to a conventional ignition system.

_____

_____

_____

_____

_____

29. List three advantages of the electronic ignition system.

a. _____

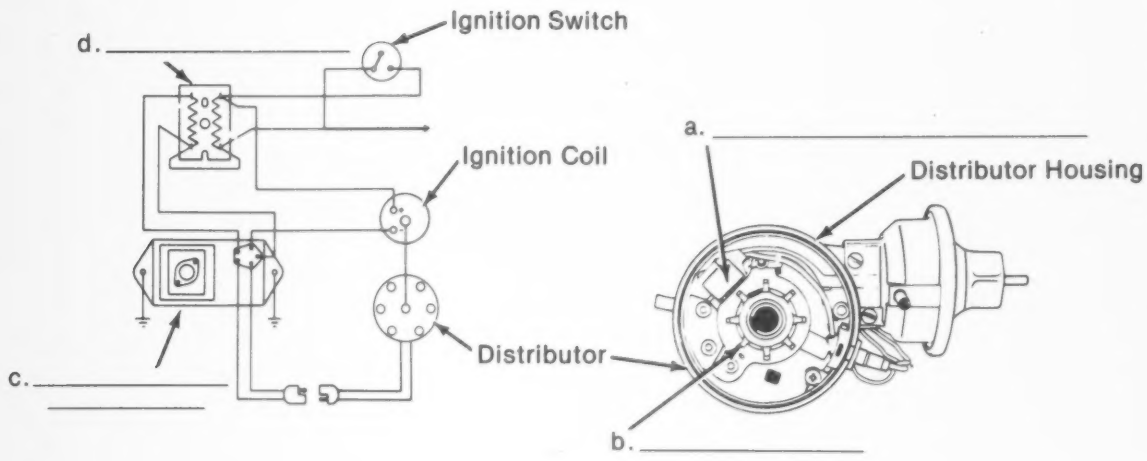
b. _____

c. _____

TEST

30. Identify major components of the electronic ignition system illustrated below. Write the correct names in the blanks.

Resistor unit **Control unit** **Magnetic-pickup assembly** **Armature**



31. Match components of the electronic ignition system to their correct functions. Write the correct numbers in the blanks.

_____a. Controls flow of current in primary winding of ignition coil and maintains dwell

_____b. Maintains constant primary current with variations in engine speed

_____c. Rotates with distributor shaft, producing a voltage pulse in magnetic pickup

_____d. Sends a small voltage pulse to the control unit to trigger switching transistor to stop current flow in coil primary winding

1. Resistor unit
2. Magnetic-pickup assembly
3. Armature
4. Control unit

TEST

32. Arrange in order the steps in electronic ignition system operation. Write a "1" in the blank before the first step, a "2" before the second step, and so on.

_____a. As armature tooth aligns with magnetic pickup, voltage in magnetic-pickup circuit is sufficient to signal switching transistor to shut off current flow in primary circuit

_____b. With ignition switch on and armature tooth not aligned with magnetic pickup, primary circuit has current flowing from ignition switch to resistor unit (if used), through primary winding of coil, through control unit to ground

_____c. With primary circuit open, magnetic field in coil collapses and induces a high-voltage surge in secondary circuit

_____d. As armature tooth approaches magnetic pickup, voltage begins to build in magnetic-pickup circuit

33. State the purpose of the charging system.

_____

_____

34. Match terms associated with charging systems to their correct definitions. Write the correct numbers in the blanks.

_____a. Maximum DC amperage an alternator can produce

_____b. Wire touching another wire and providing a shorter path for current to flow

_____c. Circuit in which a wire is broken or disconnected

_____d. Circuit in which a wire touches ground, causing current to flow to ground instead of through circuit

_____e. Group of diodes that converts alternating current to direct current

_____f. Stator winding with a positive and negative diode

_____g. Device that allows current to flow in one direction and blocks current in opposite direction

1. Phase
2. Grounded circuit
3. Diode
4. Rectifier
5. Rated output
6. Short circuit
7. Open circuit

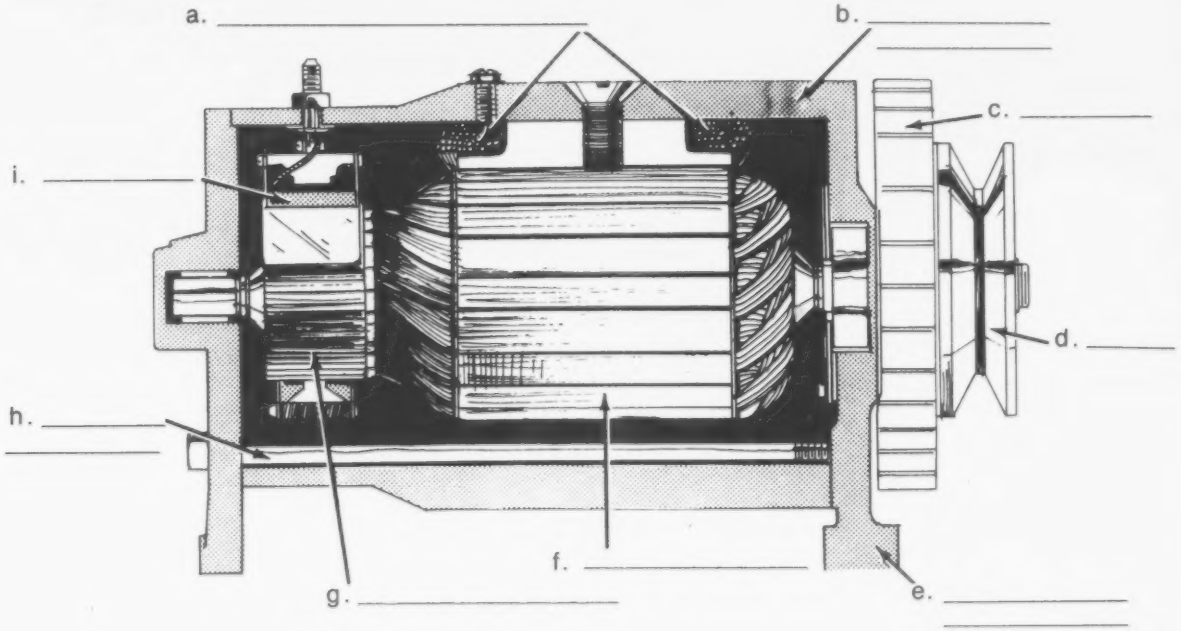
TEST

35. Match charging-system components to their correct purposes. Write the correct numbers in the blanks.

_____a.	Supplies electrical power for starting and operating electrical system during slow generator speed or heavy electrical load	1. Generator or alternator
_____b.	Indicates a "no charge" condition in charging system	2. Battery
_____c.	Controls generator voltage and current output	3. Regulator
_____d.	Supplies electricity to battery and electrical system when driven mechanically by engine	4. Indicator light
_____e.	Measures rate of current flow	5. Ammeter

36. Identify major parts of the generator illustrated below. Write the correct names in the blanks.

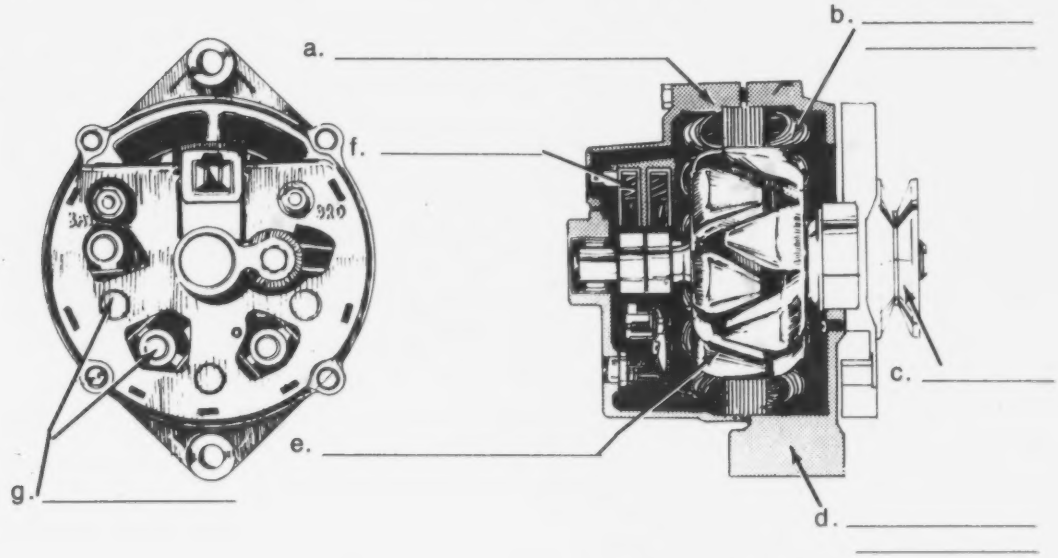
Pulley **Drive end frame** **Field coils** **Commutator**
Fan **Generator housing** **Through bolt** **Armature**
Brushes



TEST

37. Identify major parts of the alternator illustrated below. Write the correct names in the blanks.

Slip-ring end frame **Rotor assembly** **Drive end frame**
Brush assembly **Pulley** **Stator assembly**
Diodes



38. Distinguish between generator and alternator. Write a "G" in the blanks before generator and an "A" in the blanks before alternator.

_____a. Rotates field inside stationary windings

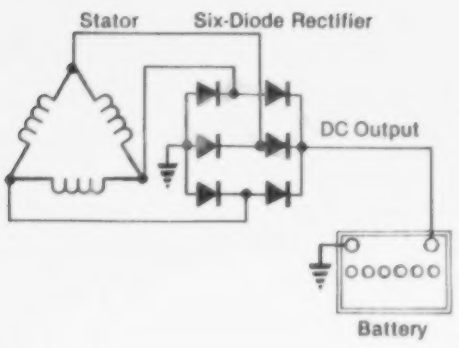
_____b. Rotates armature windings inside field

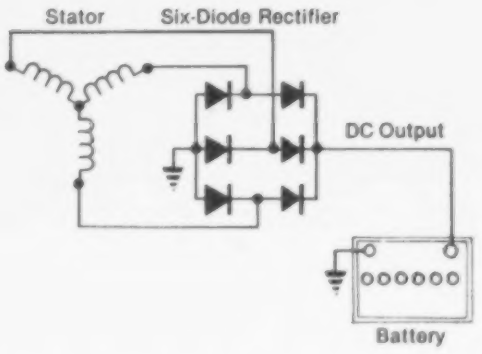
_____c. Rectifies AC current to DC with a series of diodes

_____d. Rectifies current through use of a segmented commutator and brushes

TEST

39. Label types of stator windings illustrated below. Write the correct names in the blanks.





a. _____ b. _____

40. Describe how current and voltage are regulated in an alternator.

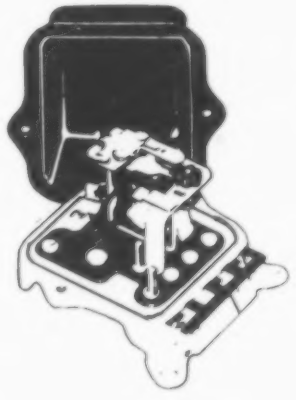
a. Current — _____

_____

b. Voltage — _____

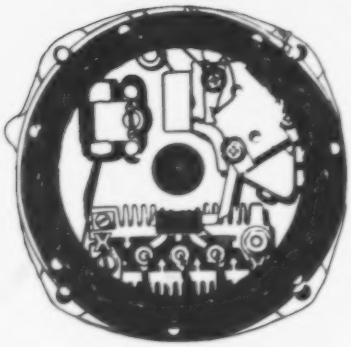
_____

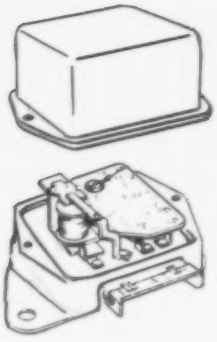
41. Label types of voltage regulators for alternators. Write the correct names in the blanks.



a. _____ b. _____

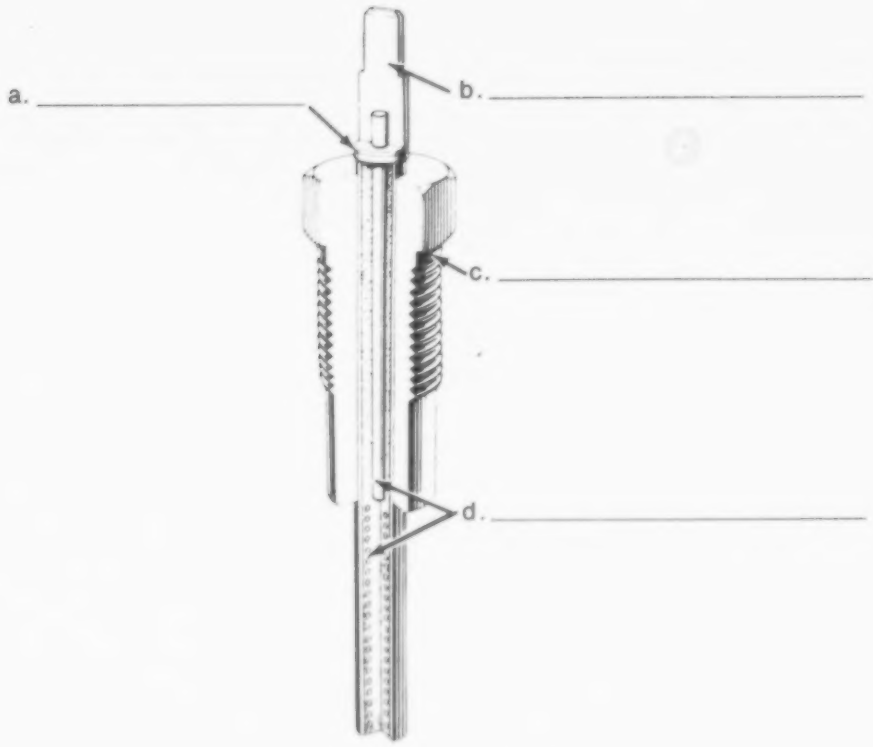
TEST





c. _____ d. _____

42. Label parts of the glow plug illustrated below. Write the correct names in the blanks.



TEST

43. Discuss glow plug operation — _____

_____

_____

_____

_____

_____

_____

_____

(NOTE: Test question 44 lists the job sheets. They are an important part of this test. If they have not been completed, check with your instructor.)

44. Demonstrate the ability to

a. Construct a series circuit.

b. Construct a parallel circuit.

c. Clean and service a battery.

d. Remove and replace a battery.

e. Measure battery electrolyte with a hydrometer.

f. Load test a battery.

g. Charge test a battery for three minutes.

h. Start engine using a negative-ground booster battery.

i. Use a 24-volt battery-booster system to start a vehicle with a 12-volt system.

j. Load test a starter.

k. Test starter-circuit resistance.

l. Test starter control-circuit resistance.

m. Remove and replace a starter.

n. Disassemble, check, and reassemble a starter.

TEST

o. Check and set ignition timing.

p. Remove and replace a distributor.

q. Remove and replace contact points and condenser.

r. Adjust dwell on an externally adjustable distributor.

s. Test and adjust distributor on distributor tester.

t. Remove, inspect, service, and replace spark plugs.

u. Remove and replace a generator.

v. Disassemble, check, and reassemble a generator.

w. Remove and replace and alternator.

x. Disassemble, check, and reassemble an alternator.

y. Test alternator charging-circuit resistance.

z. Test alternator current output.

aa. Test external-type voltage regulator.

bb. Test internal-type voltage regulator on vehicle.

ELECTRICAL SYSTEMS
UNIT V

ANSWERS TO TEST

1.

a.	6	h.	3	n.	17
b.	4	i.	7	o.	18
c.	1	j.	10	p.	14
d.	8	k.	2	q.	16
e.	5	l.	13	r.	15
f.	11	m.	12	s.	19
g.	9				

2. a. Current
   b. Voltage
   c. Resistance

3. Discussion should include the following
   a. Voltage — Difference in electrical pressure measured between two points in a circuit
   b. Amperage — Rate of electron flow
   c. Ohms — Opposition (resistance) to current flow

4. a, c, d, f

5. a. Source
   b. Conductor
   c. Load
   d. Switch

ANSWERS TO TEST

6. a. Parallel
   b. Series
   c. Series-parallel

7. a. Diode (one-way)
   b. Battery
   c. Inductor
   d. Contact points
   e. Motor (DC)
   f. Ammeter
   g. Spark gap
   h. Thermal element
   i. Condenser (capacitor)
   j. Transistor
   k. Negative terminal
   l. Lamp
   m. Switch (closed)
   n. Fixed resistor
   o. Circuit breaker
   p. Ground
   q. Zener diode
   r. Fuse
   s. Switch (open)
   t. Ohm
   u. Coil
   v. Alternator
   w. Variable resistor
   x. Fusible link or wire
   y. Positive terminal
   z. Voltmeter

8. a. Ohmmeter
   b. Voltmeter
   c. Ammeter

9. a

10. a. Supplies current for cranking engine
    b. Supplies current when demand exceeds output of charging system
    c. Stabilizes voltage in system during operation

ANSWERS TO TEST

11. Answer should include any two of the following

    a. Two dissimilar metals placed in acid solution produce chemical action

    b. The more active metal loses electrons and becomes positively charged

    c. The less active metal accumulates electrons and becomes negatively charged

12. a. 3

    b. 1

    c. 2

13. a, b, c, e, f

14. a. 3 e. 4

    b. 1 f. 7

    c. 2 g. 6

    d. 5 h. 8

15. To convert electrical energy from battery into mechanical energy at starter in order to crank engine

16. a. Key switch d. Starter

    b. Battery cable e. Starter switch

    c. Battery f. Small-gauge switch wire

17. a. 3

    b. 1

    c. 4

    d. 2

ANSWERS TO TEST

18.

a.	Starter frame	h.	Pole shoe
b.	Through bolt	i.	Armature
c.	Solenoid	j.	Commutator
d.	Shift lever	k.	End frame
e.	Drive housing	l.	Bushing
f.	Starter drive	m.	Starter brush
g.	Field coil		

19. To provide a high-voltage spark to ignite the fuel/air mixture in the combustion chamber

20.

a.	Breaker cam	h.	Primary ignition wire
b.	Spark-advance mechanism	i.	Ignition switch
c.	Condenser	j.	Battery
d.	Contact points	k.	Ignition coil
e.	Rotor	l.	Distributor cap
f.	Secondary ignition cable	m.	Distributor
g.	Primary resistance unit	n.	Spark plug

21.

a.	6	f.	5	k.	11
b.	9	g.	3	l.	14
c.	12	h.	7	m.	10
d.	2	i.	1	n.	4
e.	8	j.	13		

22.

a.	Centrifugal advance mechanism	d.	Distributor cam
b.	Condenser	e.	Primary lead wire
c.	Vacuum advance unit	f.	Breaker plate

ANSWERS TO TEST

	g.	Distributor drive gear		j.	Rotor
	h.	Distributor housing		k.	Distributor cap
	i.	Contact points			

23.	a.	P	e.	S	i.	S
	b.	P	f.	S	j.	P
	c.	S	g.	P	k.	S
	d.	P	h.	P	l.	P

24.	a.	3	d.	1
	b.	2	e.	4
	c.	5		

25.	a.	Ignition-cable terminal	e.	Ground electrode
	b.	Center-electrode resistance unit	f.	Steel shell
	c.	Gas seal	g.	Porcelain insulator
	d.	Center-electrode tip		

26.	a.	2	e.	7
	b.	5	f.	4
	c.	6	g.	3
	d.	1	h.	8

27.	a.	C
	b.	T
	c.	T
	d.	C

ANSWERS TO TEST

28. Discussion should include the following

The electronic ignition system functions the same as the conventional system; however, in the electronic system, an electric control unit and its sensory device, a magnetic pickup, do the job of the ignition points in a conventional system

29. Answer should include any three of the following

a. Requires much less maintenance during life of vehicle

b. Has no moving parts in primary circuit

c. Maintains a constant dwell at all engine speeds and operating conditions

d. Extends the efficient life of the spark plugs

30. a. Magnetic-pickup assembly
b. Armature
c. Control unit
d. Resistor unit

31. a. 4
b. 1
c. 3
d. 2

32. a. 3
b. 1
c. 4
d. 2

33. To recharge the battery and maintain a supply of electrical current to meet the operating needs of the vehicle

34. a. 5
b. 6
c. 7
d. 2
e. 4
f. 1
g. 3

ANSWERS TO TEST

35. a. 2 d. 1
    b. 4 e. 5
    c. 3

36. a. Field coils
    b. Generator housing
    c. Fan
    d. Pulley
    e. Drive end frame
    f. Armature
    g. Commutator
    h. Through bolt
    i. Brushes

37. a. Slip-ring end frame
    b. Stator assembly
    c. Pulley
    d. Drive end frame
    e. Rotor assembly
    f. Brush assembly
    g. Diodes

38. a. A
    b. G
    c. A
    d. G

39. a. Delta-connected
    b. Wye-connected

40. Description should include the following
    a. Current — Regulated by number of turns of wire in each phase
    b. Voltage — Regulated by controlling current flow in rotor field

ANSWERS TO TEST

41. a. Electronic external
    b. Electromechanical
    c. Electronic internal
    d. Transistorized

42. a. Washer
    b. Terminal
    c. Body
    d. Heating element

43. Discussion should include the following

    Activating glow plug for correct length of time heats precombustion chambers to a temperature that is necessary for combustion when engine is turned on. Glow plugs continue to heat precombustion chamber until engine is running smoothly.

44. Performance skills evaluated to the satisfaction of the instructor

HYDRAULIC SYSTEMS
UNIT I

UNIT OBJECTIVE

After completing this unit, the student should be able to identify components of the hydraulic system, change oil in the system, and repair and replace components of the system. The student will show this knowledge by completing job sheets and unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match to their correct definitions terms associated with hydraulic systems.
2. Select from a list basic principles of hydraulics.
3. Select from a list correct statements about hydraulic force theory.
4. Identify components of a hydraulic system.
5. Name basic types of hydraulics.
6. Select from a list functions of the hydraulic system.
7. Distinguish between mechanical and hydraulic balanced directional control valves.
8. Describe the purpose of hydraulic valves.
9. Label common types of hydraulic valves.
10. Name major types of hydraulic cylinders.
11. Label types of pumps used in hydraulic systems.
12. Describe the purpose of hydraulic pumps.
13. List major uses of hydraulic accumulators.
14. Label major types of hydraulic accumulators.
15. Label types of hydraulic-system filters.
16. Name classifications of filters.
17. Explain why filters are used.

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OBJECTIVE SHEET

18. List probable causes of trouble in a hydraulic system.

19. Demonstrate the ability to

    a. Change oil in a hydraulic system.

    b. Disassemble, inspect, and reassemble a directional control valve.

    c. Disassemble, inspect, and reassemble a gear pump.

    d. Remove and replace the packing gland on a piston rod.

HYDRAULIC SYSTEMS
UNIT I

SUGGESTED ACTIVITIES

I. Suggested activities

A. Order materials planned to supplement unit.

(NOTE: Engine manufacturers are excellent sources for slide and film presentations on hydraulic systems. Write directly to the appropriate company or manufacturer.)

B. Obtain transparencies.

(NOTE: Transparencies are available from AGC and CIMC.)

C. Gather equipment and materials for job sheet demonstrations.

D. Provide students with objective sheet.

E. Discuss unit and specific objectives.

F. Provide students with information and job sheets.

G. Discuss information sheet.

H. Demonstrate and discuss procedures outlined in job sheets.

I. Give test.

J. Complete appropriate section of competency profiles.

(NOTE: Competency profiles are available from AGC and CIMC.)

II. Instructional materials

A. Objective sheet

B. Suggested activities

C. Information sheet

D. Transparency masters

1. TM #1 — Basic Principles of Hydraulics
2. TM #2 — Components of a Hydraulic System
3. TM #3 — Balanced Valve Operation (Mechanical)

SUGGESTED ACTIVITIES

4. TM #4 — Balanced Valve Operation (Hyraulic)

5. TM #5 — Hydraulic Cylinders

6. TM #6 — Uses of Hydraulic Accumulators

7. TM #7 — Location of Filters in Hydraulic System

E. Job sheets

1. Job Sheet #1 — Change Oil in a Hydraulic System

2. Job Sheet #2 — Disassemble, Inspect, and Reassemble a Directional Control Valve

3. Job Sheet #3 — Disassemble, Inspect, and Reassemble a Gear Pump

4. Job Sheet #4 — Remove and Replace the Packing Gland on a Piston Rod

F. Test

G. Answers to test

III. Unit references

A. Armstrong, Ivan J., and Mike Bundy. *Specialized Units in Auto Mechanics.* Stillwater, Oklahoma: State Department of Vocational and Technical Education/Curriculum and Instructional Materials Center, 1979.

B. Decker, Robert L. *Hydraulics.* Stillwater, Oklahoma: State Department of Vocational and Technical Education/Mid-America Vocational Curriculum Consortium, 1980.

C. *FOS, Fundamentals of Service, Hydraulics,* 2nd ed. Moline, Illinois: Deere and Company, 1972.

HYDRAULIC SYSTEMS
UNIT I

INFORMATION SHEET

I. Terms and definitions

A. Accumulator — Machine that stores fluid under pressure to create hydraulic energy

B. ATF — Abbreviation for *automatic transmission fluid*

C. Cross-threaded — Pertaining to threaded fittings that are started crooked

D. Displacement — Volume of oil displaced by one complete stroke or revolution

E. Force multiplication — Basic principle of hydraulics whereby the force applied to pressurize a fluid is increased in direct proportion to the difference in surface area of the two pistons

F. Hydraulic pressure — Force exerted by a fluid as a result of an attempt to compress the fluid

G. Hydraulics — Branch of science dealing with the use of liquids under pressure

H. Kinetic energy — Energy in motion

EXAMPLES: Wind, flowing water

I. Noncompressibility — Inability of fluids to be reduced in volume by pressure

J. Pascal's law — Law of hydrostatics stating that in a perfect fluid the pressure exerted on it anywhere is transmitted undiminished in all directions

K. Potential energy — Energy at rest

EXAMPLE: A compressed spring

L. Pounds per square inch (psi) — Measurement of hydraulic pressure

M. Reservoir — Container for holding a supply of fluid

II. Basic principles of hydraulics (Transparency #1)

A. Liquids have no shape of their own

B. Liquids will not compress

INFORMATION SHEET

C. Liquids transmit applied pressure in all directions

D. Liquids provide great increases in work force

E. Liquids in a confined space can be used to transmit force

III. Hydraulic force theory (Figures 1-7)

(NOTE: The following principles come from Pascal's law.)

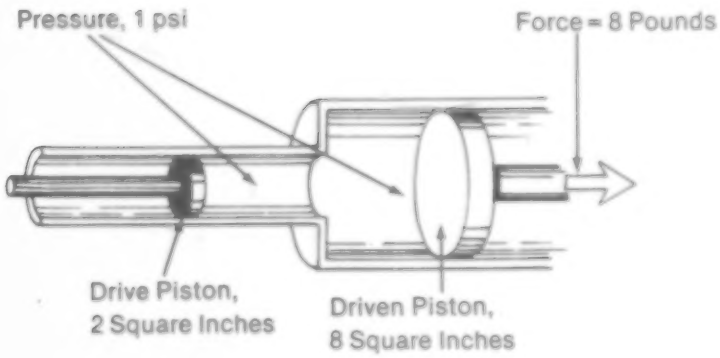
A. The force applied to a piston is increased as its area increases

EXAMPLE: Force = Pressure x Area of Driven Piston

= 1 psi x 2 sq in

= 8 lb

FIGURE 1



INFORMATION SHEET

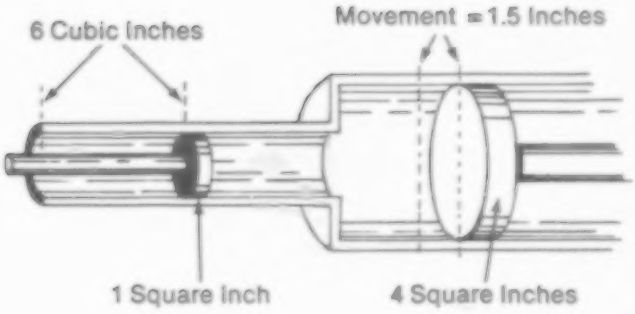
B. Piston movement is in direct proportion to areas of the two pistons

EXAMPLE: Movement = Volume Displaced by Drive Piston ÷ Area of Driven Piston

= 6 cu in ÷ 4 sq in

= 1.5 in

FIGURE 2



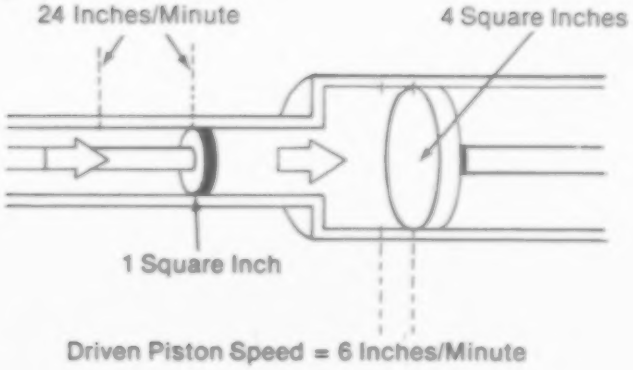
C. Rate of fluid flow to driven piston determines its speed

EXAMPLE: Driven Piston Speed = Drive Piston Speed × Area of Drive Piston ÷ Area of Driven Piston

= 24 in/min × 1 sq in ÷ 4 sq in

= 6 in/min

FIGURE 3



INFORMATION SHEET

D. System pressure overcomes friction and lifts load

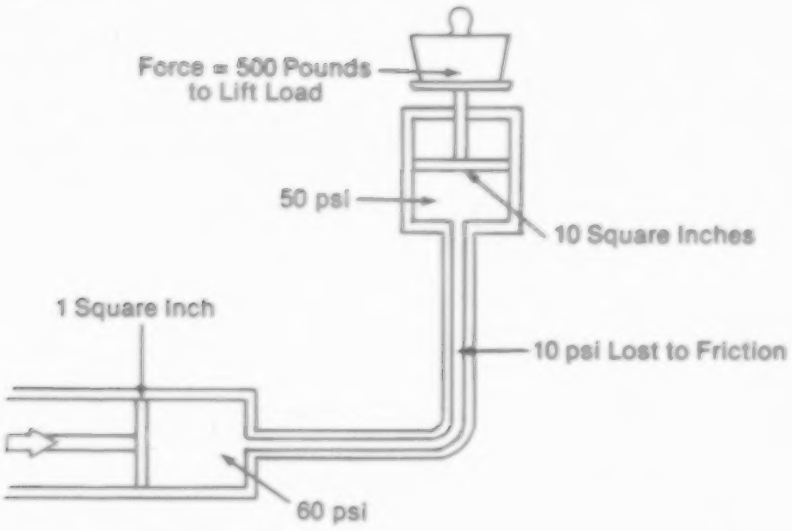
(NOTE: The resistance to fluid flow or friction causes some pressure loss. In the example, 60 psi pressure was necessary in the drive cylinder to maintain 50 psi in the driven cylinder.)

EXAMPLE: Force = (Pressure – Friction) x Area of Driven Piston

= (60 psi – 10 psi) x 10 sq in

= 500 lb

FIGURE 4



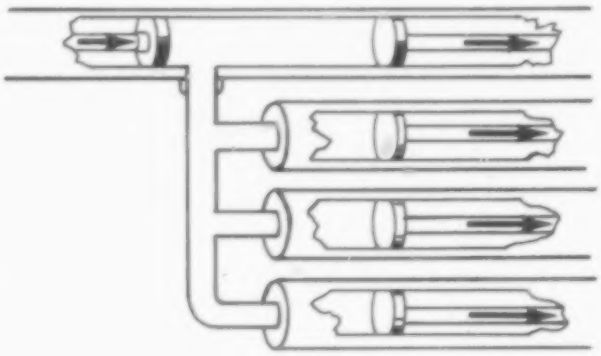
INFORMATION SHEET

E. Multicylinder systems with driven cylinders and loads of equal size produce equal force and movement in each cylinder

(NOTE: There may be a slight variation due to resistance variations.)

EXAMPLE:

FIGURE 5

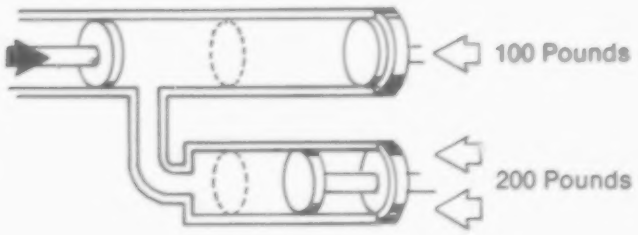


F. Driven piston area and load determine the movement in multicylinder systems

(NOTE: Given equal driven piston area and uneven load, the light-load cylinder will complete ram travel before heavy-load cylinder is moved.)

EXAMPLE:

FIGURE 6



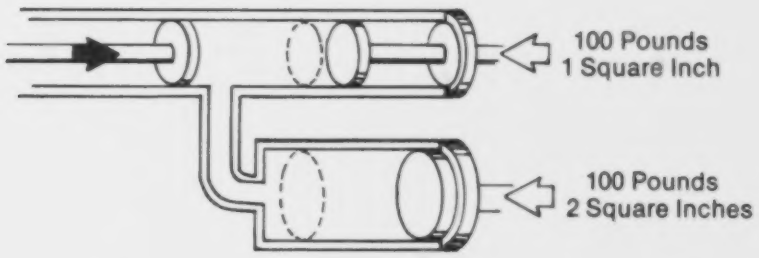
100 mm
A5
1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0
1.0 mm
1.5 mm
2.0 mm
ABCDEFGHIJKLMNOPQRSTUVWXYZ
abcdefghijklmnopqrstuvwxyz
1234567890
ABCDEFGHIJKLMNOPQRSTUVWXYZ
abcdefghijklmnopqrstuvwxyz1234567890
PG

INFORMATION SHEET

(NOTE: Given unequal driven piston area and equal load, the larger diameter piston will complete its travel before the smaller piston moves.)

EXAMPLE:

FIGURE 7



IV. Components of a hydraulic system (Transparency #2)

A. Reservoir

(NOTE: Oil is stored in the reservoir.)

B. Pump

(NOTE: The pump generates force in the system.)

C. Relief valve

D. Control valve

(NOTE: Valves regulate pressure, direction, and volume.)

E. Cylinder (actuator)

(NOTE: The cylinder converts fluid movement to mechanical energy.)

F. Connecting lines

(NOTE: The lines connect components and carry the fluid from one component to another.)

G. Air vent

INFORMATION SHEET

V. Basic types of hydraulics

A. Hydrostatic

(NOTE: The hydrostatic system supplies power by using fluids at relatively low speeds but at high pressures.)

EXAMPLE: Most hydraulic systems

B. Hydrodynamic

(NOTE: The hydrodynamic system supplies power by using fluids at high speeds "on impact.")

EXAMPLE: Torque converter

VI. Functions of the hydraulic system

A. Providing a constant flow of hydraulic fluid under pressure to operate system

B. Providing cooling to dissipate heat

C. Cleaning and lubricating moving parts of system

D. Applying pressure to the many pistons, control valves, and other moving parts

(NOTE: Pressure inside the system is measured in pounds per square inch [psi]. Changes in speed and force, equivalent to mechanical leverage advantages, are made by varying the relative area of the pistons and other movable parts.)

VII. Operation of balanced directional control valves (Transparencies #3 and #4)

A. Mechanical — Produce change in output fluid pressure proportional to movement of mechanical linkages connected to one end of valve

B. Hydraulic — Produce change in output fluid pressure proportional to varying control-fluid pressure that acts on one end of valve

VIII. Purpose of hydraulic valves — To regulate pressure, direction, and volume of oil flow throughout the hydraulic system

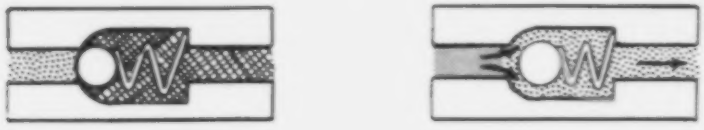
INFORMATION SHEET

IX. Common types of hydraulic valves (Figures 8-10)

A. Pressure control

(NOTE: The pressure control valve is used to limit system pressure, reduce pressure, set pressure at which oil enters a circuit, and unload a pump.)

FIGURE 8



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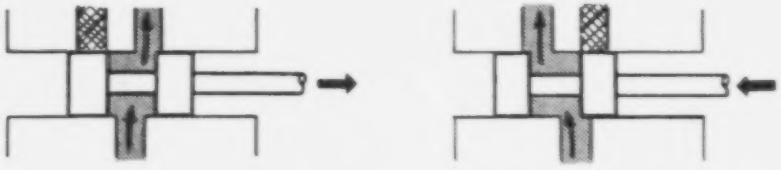
B. Directional control

(NOTE: The directional control valve is used to direct flow of oil in hydraulic systems.)

FIGURE 9



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C. Volume control

(NOTE: The volume control valve is used to control the volume or flow of oil by regulating, diverting, or stopping the flow of oil.)

FIGURE 10

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INFORMATION SHEET

X. Major types of hydraulic cylinders (single-acting and double-acting) (Transparency #5)

A. Piston-type — Gives straight movement

EXAMPLE: Allows operator to raise and lower boom and bucket

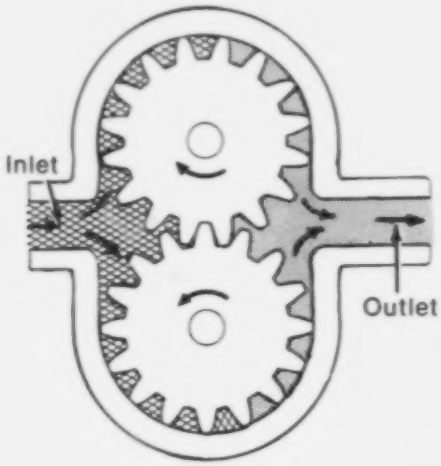
B. Vane-type — Gives rotary movement

EXAMPLE: Allows operator to swing boom and bucket

XI. Types of pumps used in hydraulic systems (Figures 11-13)

A. Gear

FIGURE 11



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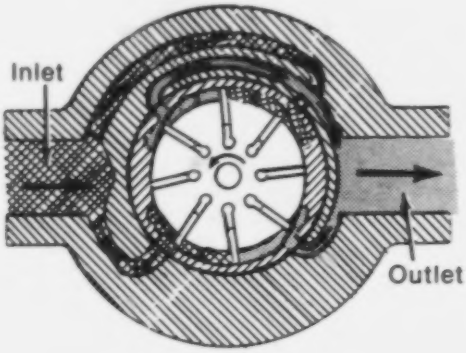
B. Vane

FIGURE 12



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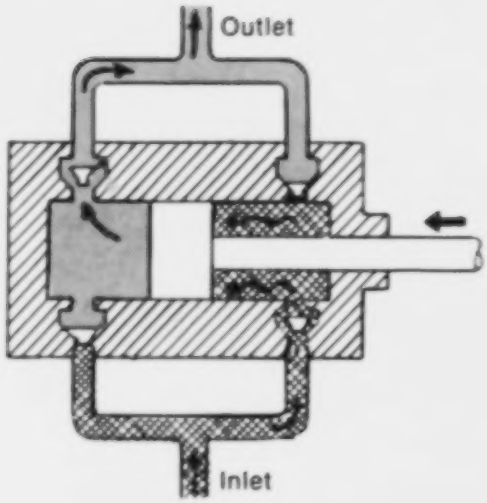
INFORMATION SHEET

C. Piston

FIGURE 13



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XII. Purpose of hydraulic pumps — To convert mechanical force to hydraulic fluid power

(NOTE: Pumps create flow and operate on a principle called *displacement.*)

XIII. Major uses of hydraulic accumulators (Transparency #6)

A. Storing energy

(NOTE: Hydraulic accumulators are often used as boosters for systems with fixed displacement pumps.)

B. Absorbing shock

(NOTE: Hydraulic accumulators take in excess oil during peak pressure and let it out after the surge is past.)

C. Building pressure gradually

(NOTE: Hydraulic accumulators absorb some of the rising oil pressure, thus slow the down stroke of the pistons.)

D. Maintaining constant pressure

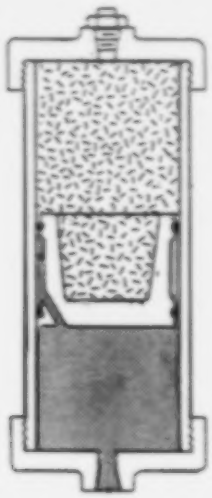
(NOTE: Hydraulic accumulators place a fixed force on the oil, thus maintain the same gravity pressure on the system.)

INFORMATION SHEET

XIV. Major types of accumulators (Figures 14-18)

A. Piston

FIGURE 14



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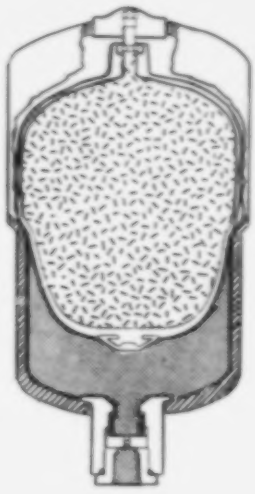
B. Bladder-type

FIGURE 15



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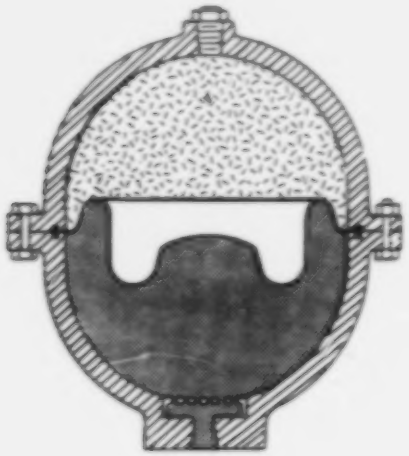
INFORMATION SHEET

C. Diaphragm

(NOTE: The pneumatic-type is operated by compressed gas.)

FIGURE 16



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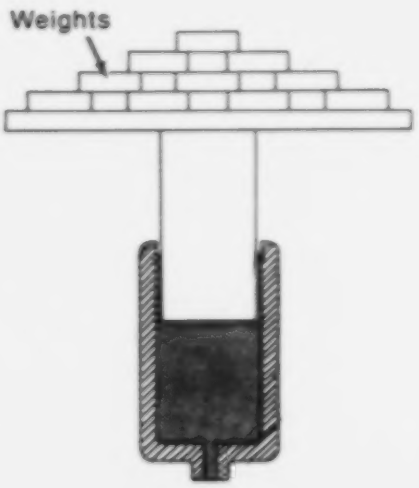
D. Weight-loaded

FIGURE 17



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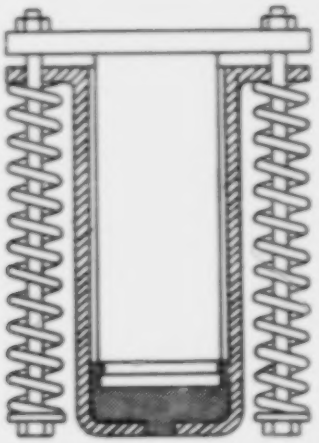
INFORMATION SHEET

E. Spring-loaded

FIGURE 18



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XV. Types of filters used in hydraulic systems (Transparency #7; Figures 19-22)

(NOTE: Filters may be located in the pump inlet line, in the return line to the reservoir, or anywhere throughout the system where needed.)

A. Wire mesh

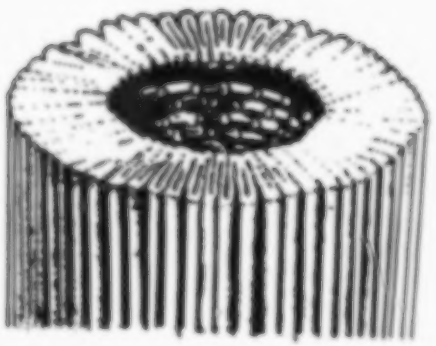
FIGURE 19

B. Metal edge

FIGURE 20

C. Pleated paper

FIGURE 21



INFORMATION SHEET

D. Cotton waste

FIGURE 22

XVI. Classifications of filters

A. Surface-type

(NOTE: Surface-type filters have a single surface that catches and removes dirt particles larger than holes in the filters as the oil passes through the holes in a straight path.)

B. Depth-type

(NOTE: Depth-type filters use a large volume of material to cause the oil to move in many different directions as it filters into the system.)

XVII. Why filters are used — To filter out contaminants in order to keep the hydraulic fluid clean

XVIII. Probable causes of trouble in a hydraulic system

A. Broken lines

B. Leaking lines

C. Dirty oil

D. Low oil in reservoir

E. Too much oil in reservoir

INFORMATION SHEET

F. Defective or worn pump

G. Defective or worn valves

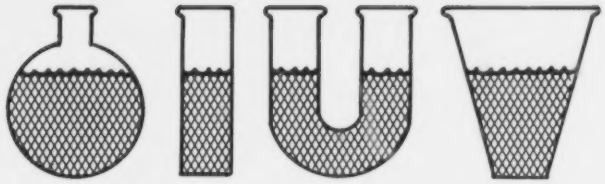
H. Leaking piston rod packings

I. Worn or broken O-rings

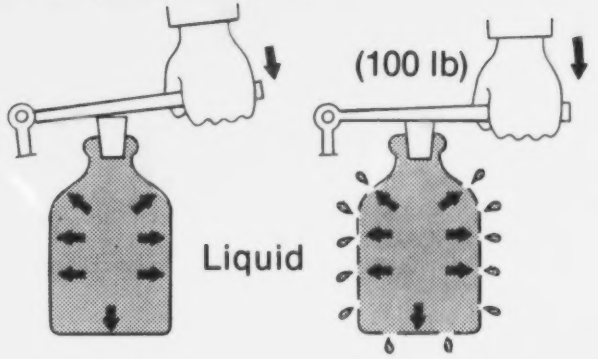
J. Defective, cross-threaded, or mismatched threads on fittings

K. Water or contamination in system

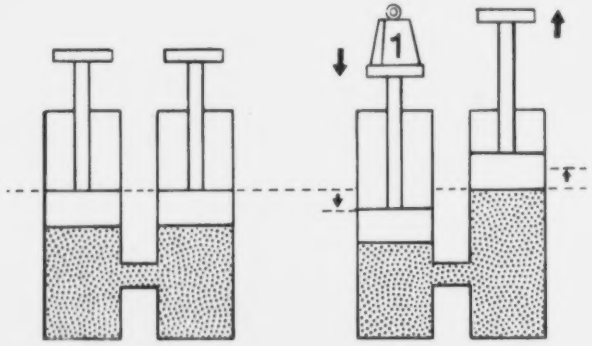
Basic Principles of Hydraulics



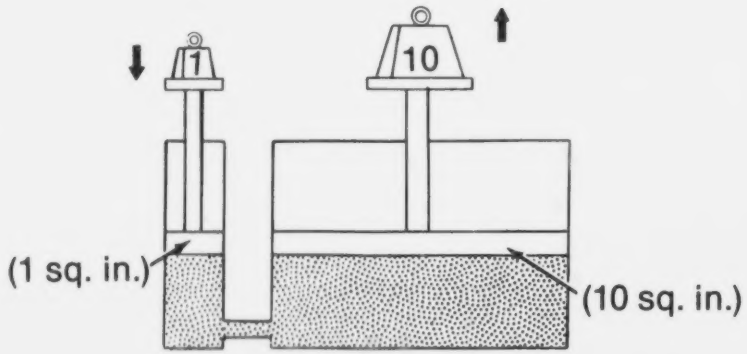
Liquids Have No Shape of Their Own



Liquids Cannot Be Compressed



Liquids Transmit Applied Pressure in All Directions



Liquids Provide Great Increases in Work Force

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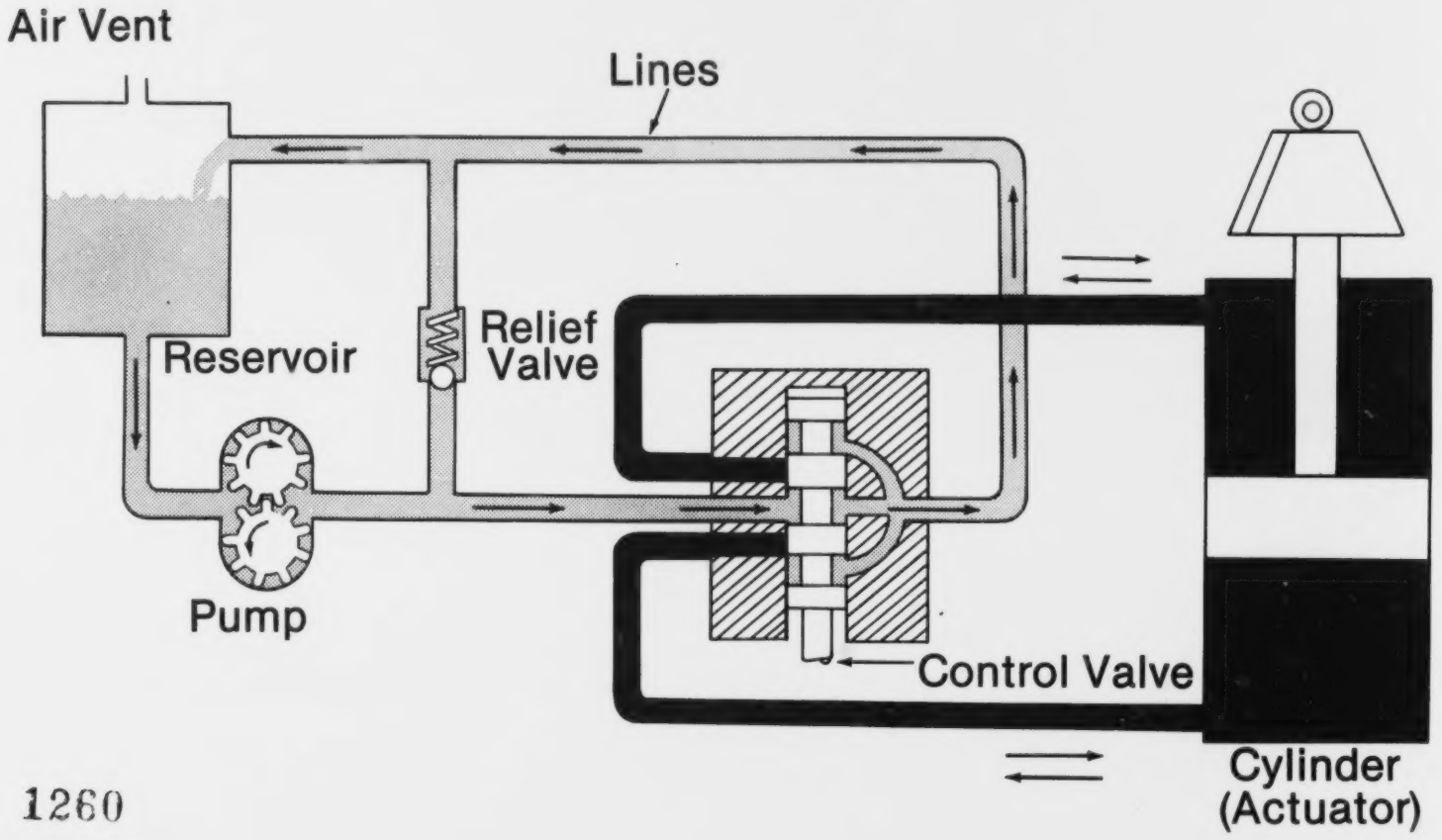
Components of a Hydraulic System



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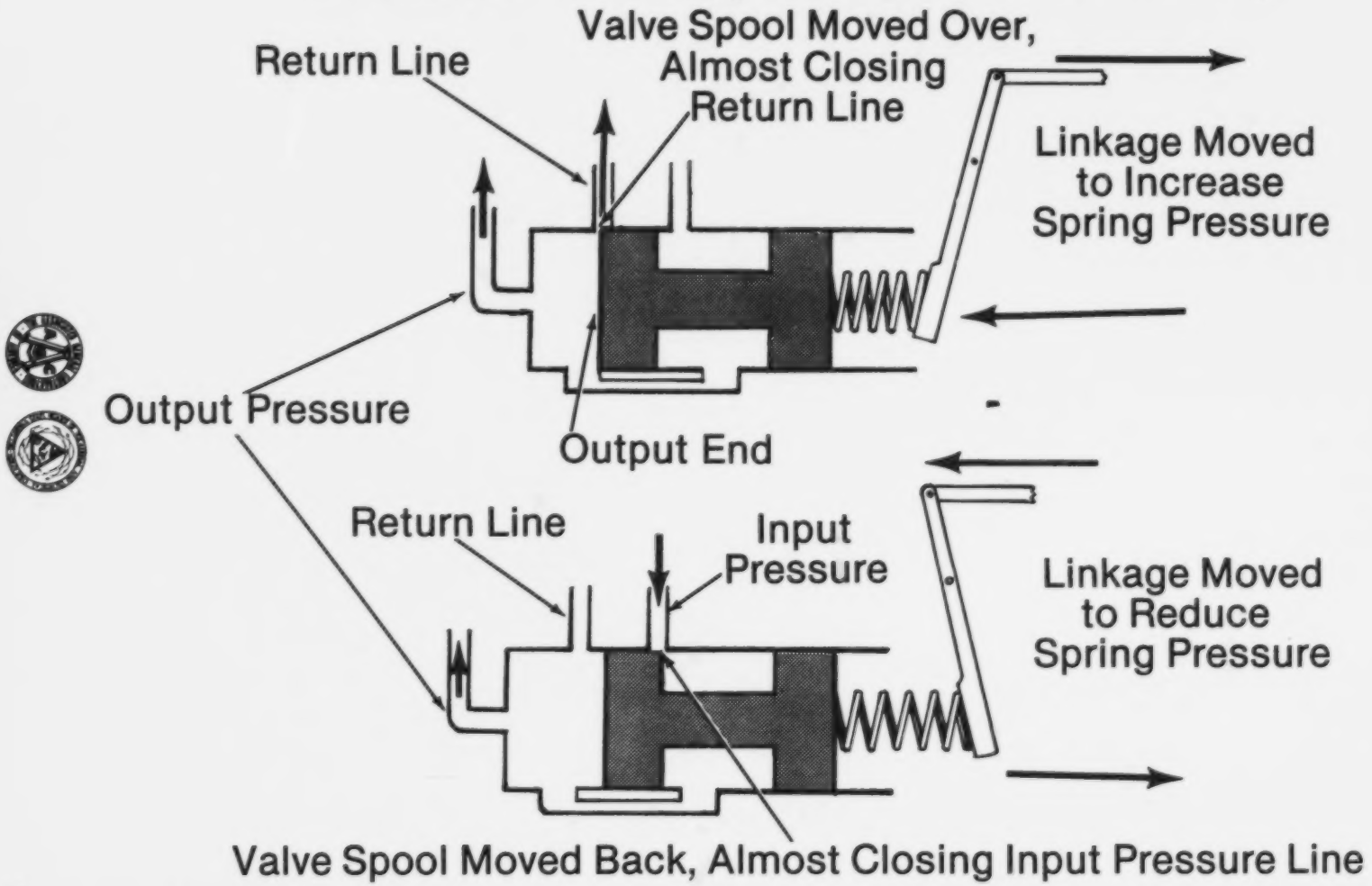
TM #2

HEM - 23-D

Balanced Valve Operation (Mechanical)



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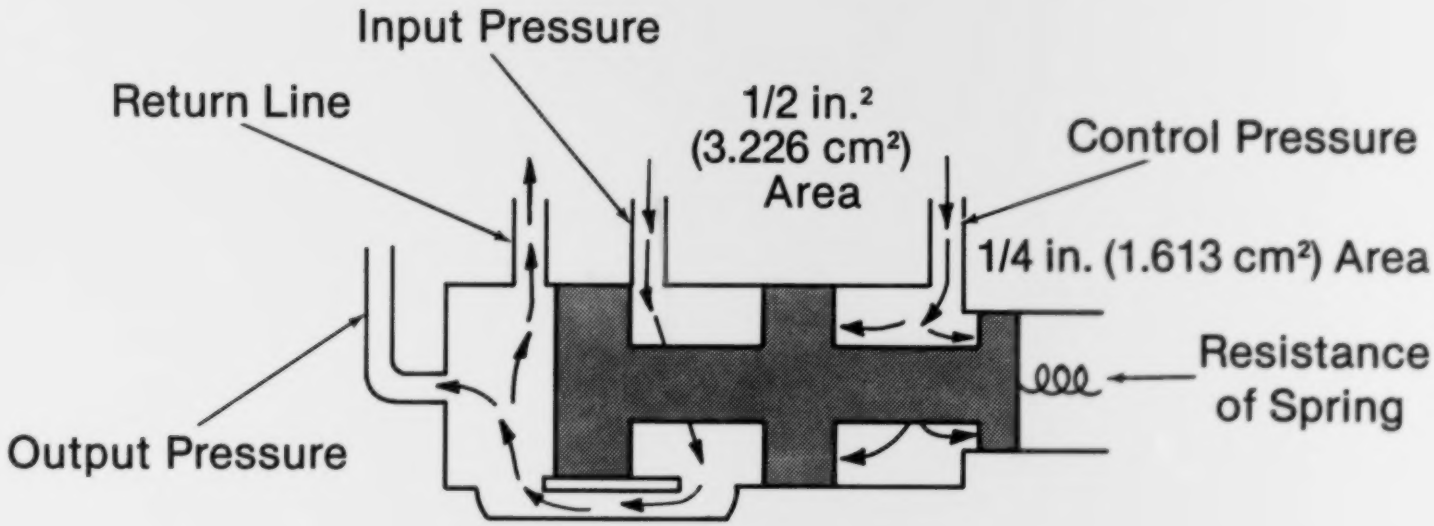
1263

TM #3

HEM - 25-D

Balanced Valve Operation (Hydraulic)



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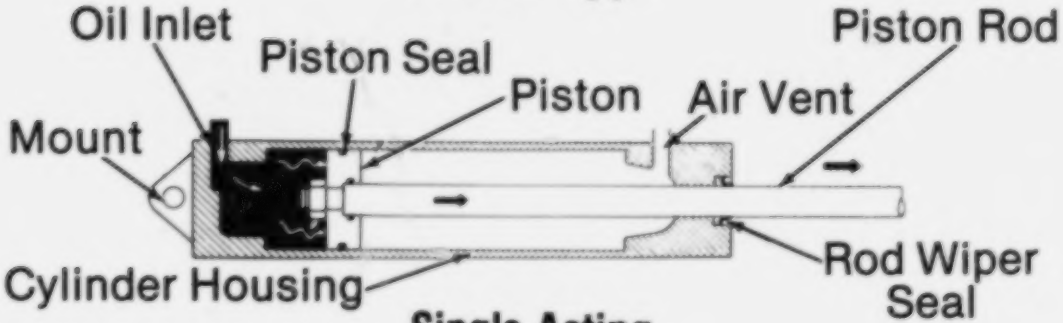
TM #4

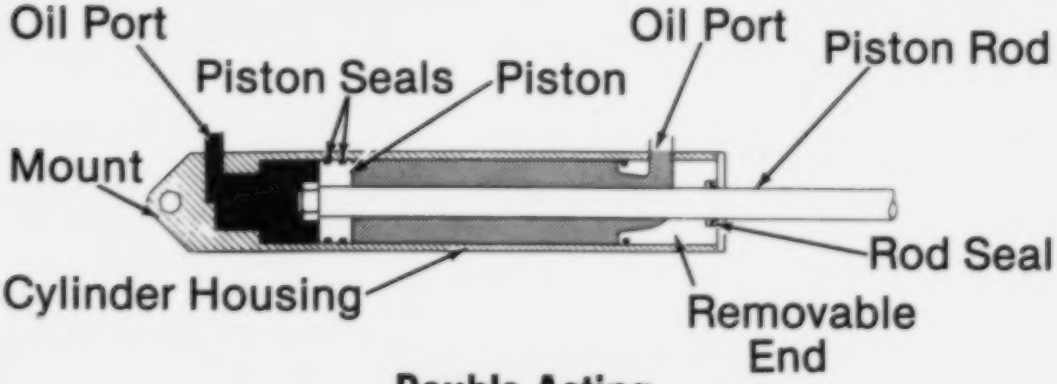
HEM - 27-D

Hydraulic Cylinders

Piston-Type

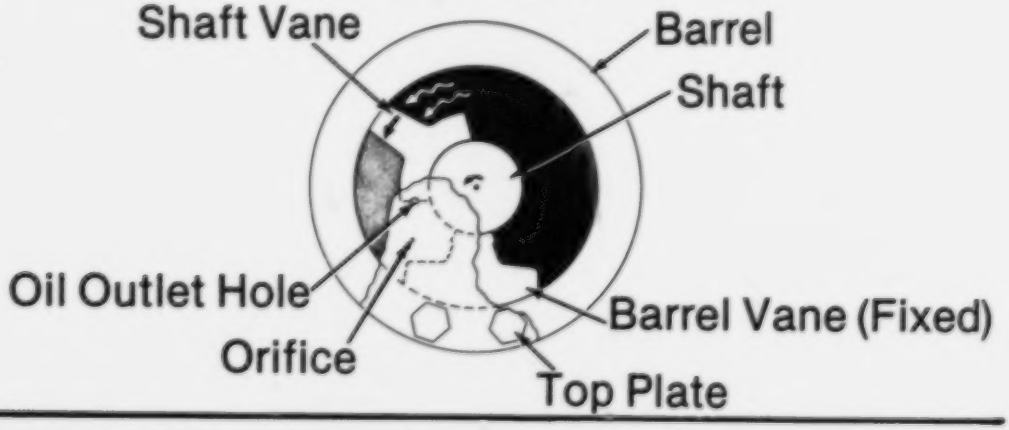


Single Acting



Double Acting

Vane-Type



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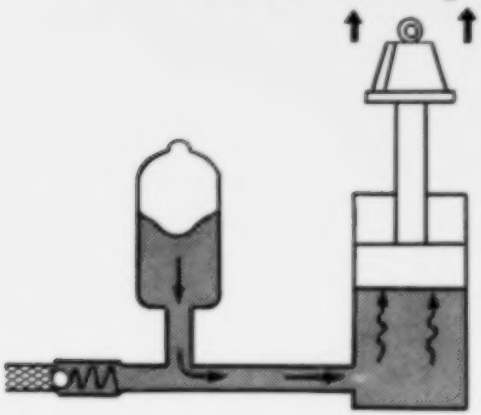
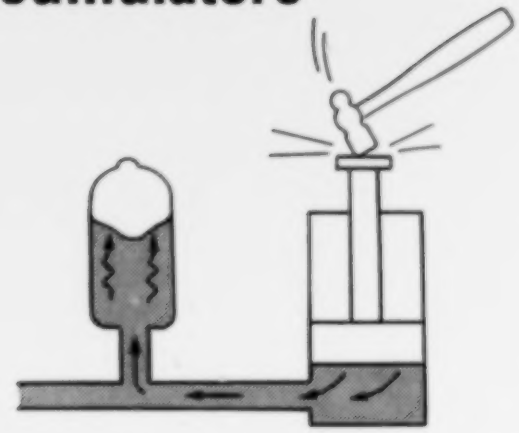
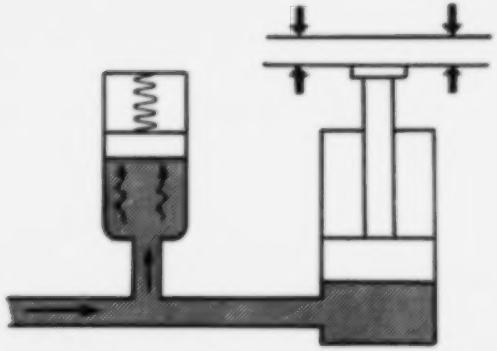
Uses of Hydraulic Accumulators



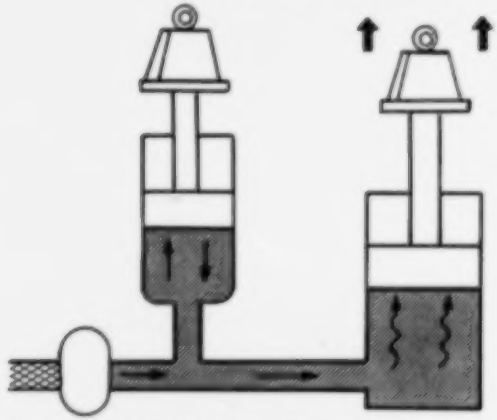
Store Energy



Absorb Shocks



Build Pressure Gradually



Maintain Constant Pressure

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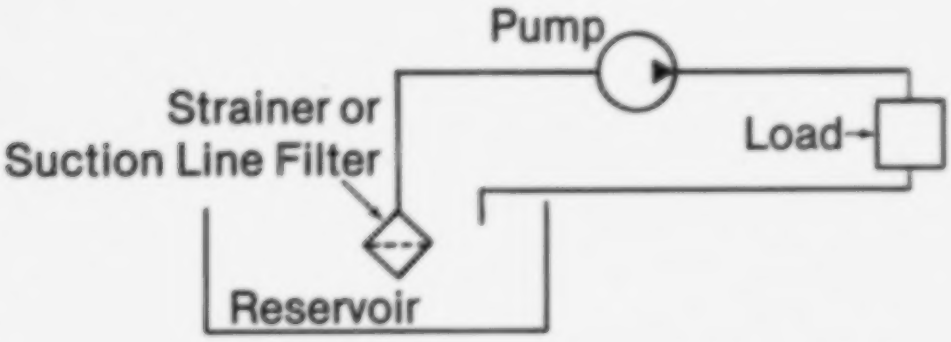
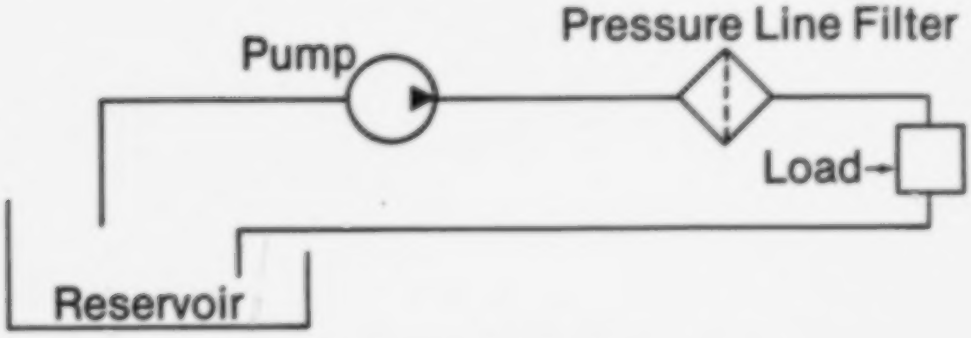
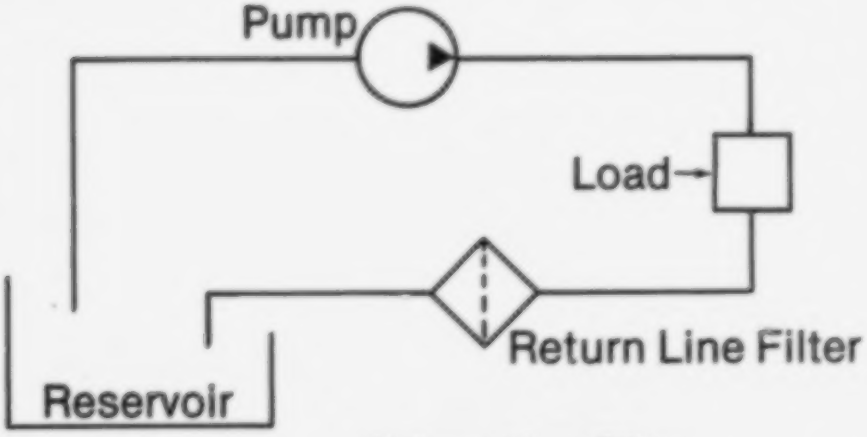
Location of Filters in Hydraulic System



Strainer or Suction Line Filter



Pressure Line Filter



Return Line Filter

HYDRAULIC SYSTEMS
UNIT I

JOB SHEET #1 — CHANGE OIL IN A HYDRAULIC SYSTEM

I. Equipment and materials

A. Tool kit

B. Oil pan for draining oil

C. New hydraulic oil

D. Pouring spout or container

E. Shop towels

F. Appropriate service manual

II. Procedure

(CAUTION: Keep dirt and other contaminants out of the system.)

(NOTE: Oil should be changed as recommended by manufacturer or at least once a year.)

A. Support machine and blade, bucket, or boom firmly

(NOTE: Nothing should be allowed to fall or change position when hydraulic support is removed.)

(CAUTION: Before disconecting parts, relieve all hydraulic pressure by cycling control levers; also discharge accumulator.)

B. Remove drain plugs from reservoirs

(NOTE: Some systems have more than one reservoir.)

C. Allow oil to drain

D. Disconnect piston rods at their outer ends

E. Move piston rods back and forth the full length of cylinder to force out the oil

F. Remove drain plug from pump and allow oil to drain

(NOTE: Some pumps do not have drain plugs.)

G. Disconnect outlet connecton from pump if there is no drain plug

JOB SHEET #1

H. Turn the pump with the engine starter until fluid stops coming out

(CAUTION: Do not run engine with system empty.)

I. Disconnect any other lines at their low points if they do not drain

J. After complete system is drained, check the oil; if oil is very dirty, flush the system until it is clean

K. Reconnect all lines

L. Install drain plug in pump

M. Install drain plugs in reservoirs

N. Reconnect piston rods

O. Refill reservoir with correct amount of oil

(NOTE: Refer to manufacturer's maintenance guide for the correct type, amount, and viscosity of oil to use.)

(CAUTION: Do not overfill reservoir.)

P. Operate all parts of system several times after filling

Q. Recheck reservoir fluid level

R. Add oil if necessary

S. Wipe off any oil that may have dripped or spilled

T. Clean work area; clean and put away all tools and equipment

HYDRAULIC SYSTEMS
UNIT I

JOB SHEET #2 — DISASSEMBLE, INSPECT, AND REASSEMBLE
A DIRECTIONAL CONTROL VALVE

I. Equipment and materials

A. Directional control valve

(NOTE: This procedure assumes that a manually operated directional control valve will be used. Other types of directional control valves may be used with minor changes to this procedure.)

B. Basic hand-tool set

C. Lint-free shop towels

D. Shipping plugs for open ports

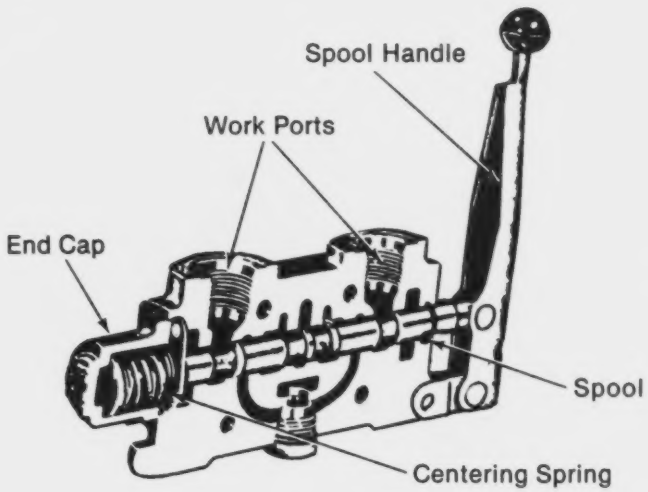
E. Safety glasses

F. Appropriate service manual

II. Procedure

(NOTE: Figure 23 shows a cutaway view of a typical directional control valve.)

FIGURE 23



JOB SHEET #2

A. Disassemble directional control valve

(NOTE: Be sure that spools are replaced in the openings from which they were removed.)

1. Install shipping plugs into valve ports
2. Clean external surfaces of valve with solvent
3. Place valve in a clean area for disassembly
4. Remove spool handle if not already removed
5. Remove end cap
6. Remove nut that holds centering spring, and remove spring
7. Carefully slide spool from valve body

B. Inspect directional control valve

(NOTE: After completing each point in the inspection, check the appropriate box and briefly describe the condition of the components.)

	✓	Condition
Examine spool for excessive wear (NOTE: The lands on the spool may become eroded from forces resulting from the fluid flow. Wear can also occur from contaminated fluid.)		
Examine spool O-ring seals, and replace if worn or nicked		
Examine valve body for cracks		

C. Reassemble directional control valve

(NOTE: Lubricate all components during reassembly.)

1. Carefully install spool into valve body, using special care to ensure that O-rings are not damaged during installation
2. Install centering spring, washers, if used, and retaining nut

JOB SHEET #2

3. Tighten nut
4. Install end cap
5. Install spool handle

D. Clean work area; clean and put away all tools and equipment

HYDRAULIC SYSTEMS
UNIT I

JOB SHEET #3 — DISASSEMBLE, INSPECT, AND REASSEMBLE
A GEAR PUMP

I. Equipment and materials

A. Gear pump

B. Basic hand-tool set

C. Solvent

D. Lint-free shop towels

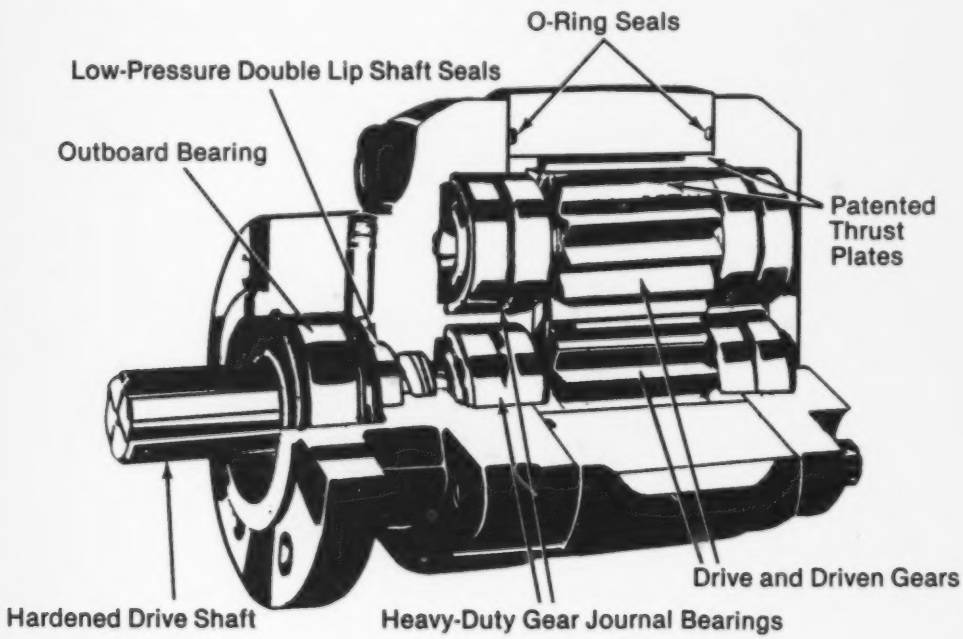
E. Safety glasses

F. Appropriate service manual

II. Procedure

(NOTE: Figure 24 shows a cutaway drawing of a typical gear pump with an outboard bearing on the pump shaft. Figure 25 on the next page is an exploded view of this pump.)

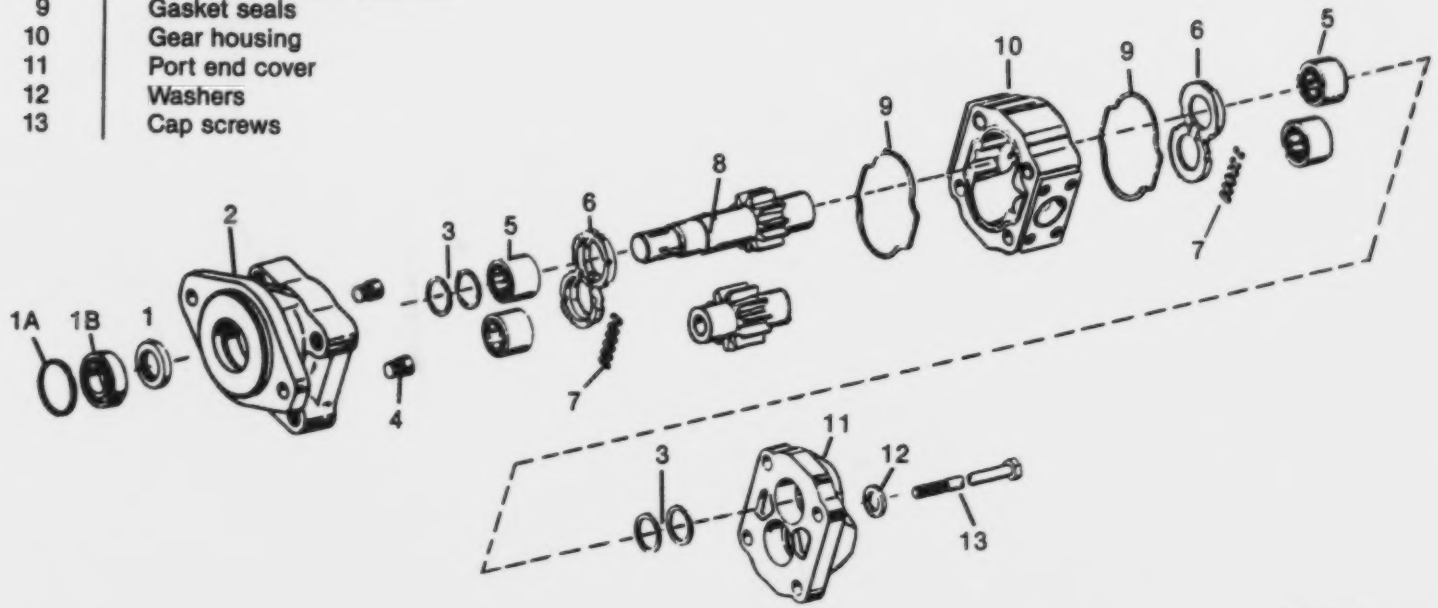
FIGURE 24



JOB SHEET #3

FIGURE 25

Item	Description
1A	Snap ring
1B	Outboard bearing
1	Double lip seal
2	Shaft end cover
3	Shaft seals
4	Check assemblies
5	Roller bearings
6	Thrust plates
7	Pocket seals
8	Integral shaft and gear set
9	Gasket seals
10	Gear housing
11	Port end cover
12	Washers
13	Cap screws



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JOB SHEET #3

A. Disassemble gear pump

1. Thoroughly clean external surfaces of pump with solvent
2. Dry pump with shop towels
3. Place pump on a clean surface for disassembly
4. Remove clip ring retainer, if gear pump is so equipped, on outboard shaft bearing
5. Remove bearing
6. Remove the four cap screws that hold pump housing together
7. Slowly remove port-end (rear) cover from pump
8. Remove the two port-side roller bearings from assembly
9. Remove rear thrust plate, and note the orientation of the plate
10. Remove gear housing from pump
11. Carefully remove the two gears from pump
12. Remove shaft-side thrust plate, noting orientation
13. Remove the two shaft-side roller bearings
14. Remove shaft seal

B. Inspect gear pump

(NOTE: After completing each point in the inspection, check the appropriate box and briefly describe the condition of the components.)

	✓	Condition
Examine the two thrust plates for excessive wear or scoring		
Examine gears for excessive wear and broken teeth		
Examine roller bearings for excessive wear and fractured bearings		
Examine shaft seal for scoring		
Examine gear housing seals (usually O-rings) for nicks or breaks		
Replace any part found to be defective		

JOB SHEET #3

C. Reassemble gear pump

(NOTE: Prelubricate parts during assembly.)

1. Carefully install shaft seal
2. Install the two shaft-side roller bearings
3. Install shaft-side thrust plate
4. Install the two gears into shaft end cover
5. Ensure that the two seals on gear housing are properly installed, and then lower gear housing around the two gears and align with shaft end cover
6. Install port-side thrust plate
7. Install port-side roller bearings
8. Install port-side end cover onto assembly; carefully align
9. Install the four cap screws
10. Torque the screws uniformly by alternately applying torque to screws on opposite sides of pump
11. Reinstall shaft outboard bearing and clip ring

D. Fill pump with fluid as necessary before operation

E. Clean work area; clean and put away all tools and equipment

HYDRAULIC SYSTEMS
UNIT I

JOB SHEET #4 — REMOVE AND REPLACE THE PACKING GLAND ON A PISTON ROD

I. Equipment and materials

- A. Piston-rod packing gland
- B. Basic hand-tool set
- C. Lock wire
- D. Shop towels
- E. Appropriate service manual

II. Procedure

- A. Cut and remove lock wire from bolts
- B. Loosen bolts all the way
- C. Pull gland back on rod
- D. Remove old packing
- E. Install new packing (usually chevron split-ring type)
  1. Install packing with peaked or convex side toward adjusting plate
  2. Arrange splits or cuts so that they are not in line with each other
- F. Lower gland on rod until it contacts packing
- G. Start all bolts, and then tighten each a little at a time until all are snug
- H. Test for leakage by moving rod in and out
- I. If there is leakage, tighten all bolts a little at a time until leak stops
- J. Reinsert new lock wire through bolt heads

  (NOTE: Lock wire is used because the bolts are adjusting bolts and cannot be tightened enough to hold themselves.)
- K. Clean work area; clean and put away all tools and equipment

HYDRAULIC SYSTEMS
UNIT I

TEST

NAME _____ SCORE _____

1. Match to their correct definitions terms associated with hydraulic systems. Write the correct numbers in the blanks.

_____a.	Branch of science dealing with the use of liquids under pressure	1. Noncompressibility
_____b.	Energy in motion	2. Kinetic energy
_____c.	Inability of fluids to be reduced in volume by pressure	3. Displacement
_____d.	Basic principle of hydraulics whereby the force applied to pressurize a fluid is increased in direct proportion to the difference in surface area of the two pistons	4. Pounds per square inch (psi)
_____e.	Machine that stores fluid under pressure to create hydraulic energy	5. ATF
_____f.	Energy at rest	6. Cross-threaded
_____g.	Force exerted by a fluid as a result of an attempt to compress the fluid	7. Hydraulic pressure
_____h.	Abbreviation for *automatic transmission fluid*	8. Force multiplication
_____i.	Law of hydrostatics stating that in a perfect fluid the pressure exerted on it anywhere is transmitted undiminished in all directions	9. Pascal's law
_____j.	Volume of oil displaced by one complete stroke or revolution	10. Hydraulics
_____k.	Pertaining to threaded fittings that are started crooked	11. Potential energy
_____l.	Measurement of hydraulic pressure	12. Reservoir
_____m.	Container for holding a supply of fluid	13. Accumulator

TEST

2. Select from the following list basic principles of hydraulics. Write an "X" in the blank before each correct answer.

_____a. Liquids will not compress

_____b. Liquids transmit applied pressure in all directions

_____c. Liquids have a specific shape of their own

_____d. Liquids in a confined space can be used to transmit force

_____e. Liquids provide great increases in work force

3. Select from the following list correct statements about hydraulic force theory. Write an "X" in the blank before each correct answer.

_____a. Rate of fluid flow to driven piston determines its speed

_____b. System pressure overcomes friction and lifts load

_____c. Force applied to driven piston is always equal to force applied to drive piston

_____d. Multicylinder systems with driven cylinders and loads of equal size produce equal force and movement in each cylinder

_____e. The force applied to a piston is increased as its area increases

_____f. Rate of fluid flow to driven piston determines its speed and force

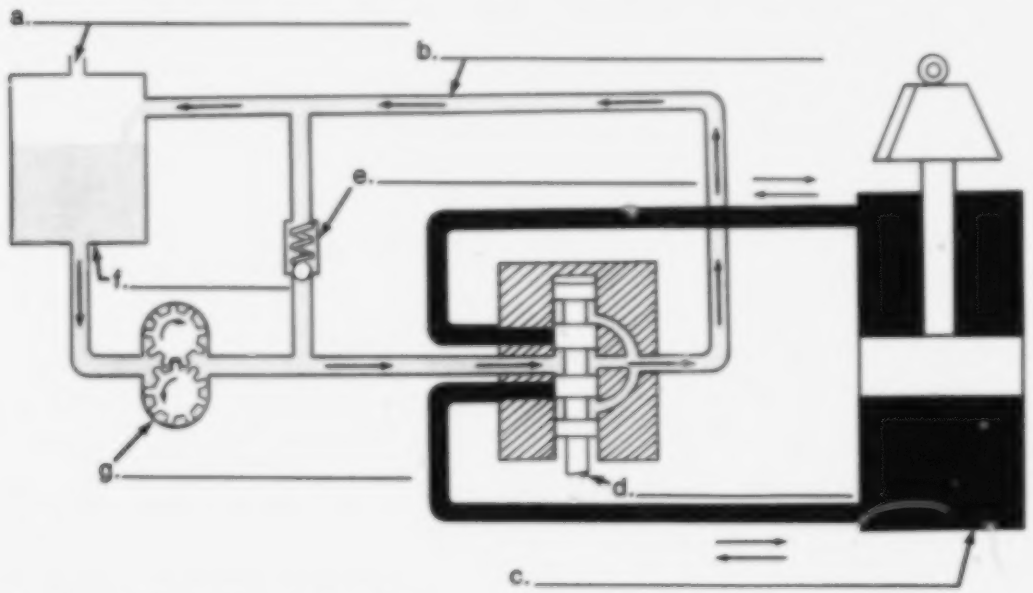
_____g. Driven piston area and load determine movement in multicylinder systems

_____h. Piston movement is in direct proportion to areas of the two pistons

TEST

4. Identify components of a hydraulic system. Write the correct names in the blanks.

Pump	**Reservoir**	**Relief valve**
Control valve	**Cylinder (actuator)**	**Lines**
Air vent		



5. Name basic types of hydraulics.

a. _____

b. _____

6. Select from the following list functions of the hydraulic system. Write an "X" in the blank before each correct answer.

_____a. Cleaning and lubricating moving parts of system

_____b. Applying pressure to the many pistons, control valves, and other moving parts

_____c. Providing a constant flow of hydraulic fluid under pressure to operate system

_____d. Providing force to dissipate heat

TEST

7. Distinguish between mechanical and hydraulic balanced directional control valves. Write an "M" in the blank before mechanical, and an "H" in the blank before hydraulic.

_____a. Produce change in output fluid pressure proportional to varying control-fluid pressure that acts on one end of valve

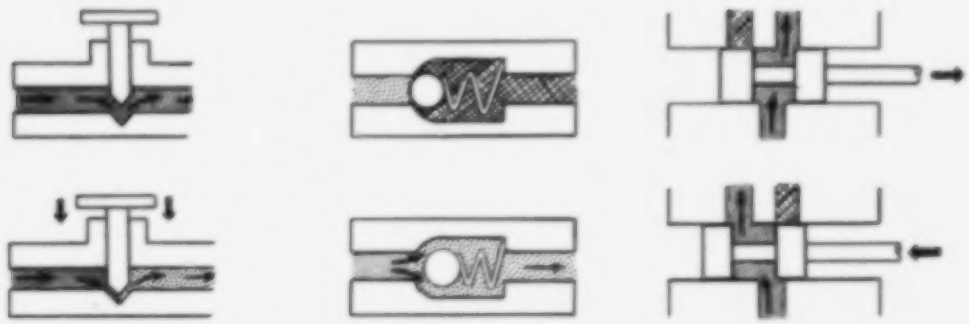
_____b. Produce change in output fluid pressure proportional to movement of mechanical linkages connected to one end of valve

8. Describe the purpose of hydraulic valves.

_____

_____

9. Label common types of hydraulic valves illustrated below.



a. _____ b. _____ c. _____

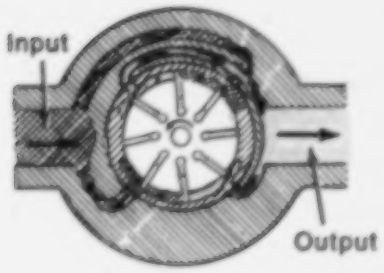
10. Name two major types of hydraulic cylinders.

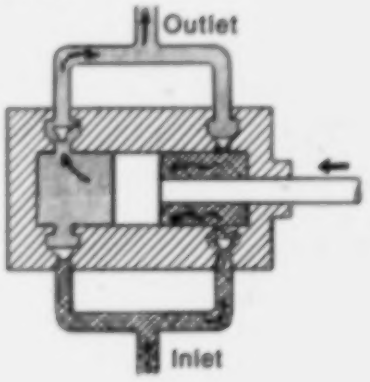
a. _____

b. _____

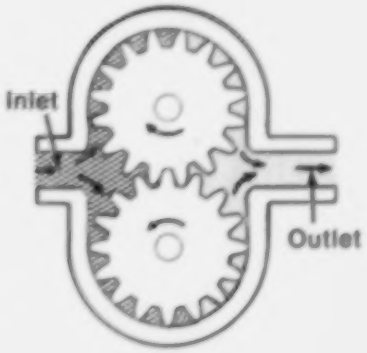
TEST

11. Label the following types of pumps used in hydraulic systems.





a. _____ b. _____



c. _____

12. Describe the purpose of hydraulic pumps.

_____

_____

13. List four major uses of hydraulic accumulators.

a. _____

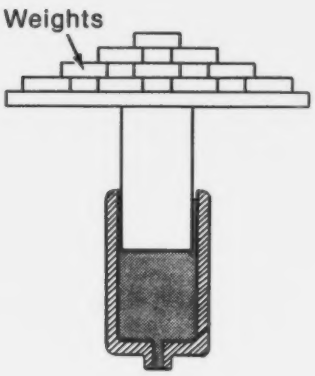
b. _____

c. _____

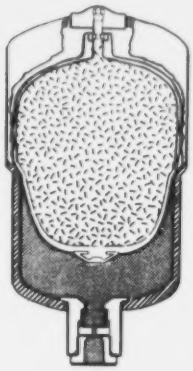
d. _____

TEST

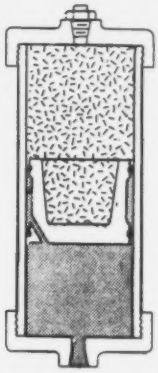
14. Label the major types of hydraulic accumulators illustrated below.



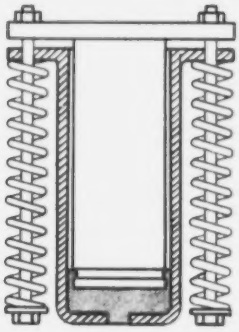
a. _____



b. _____

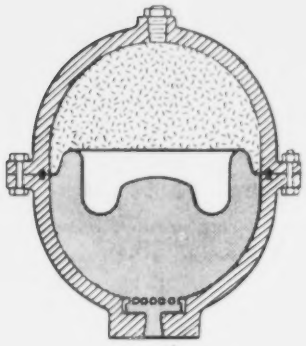


c. _____



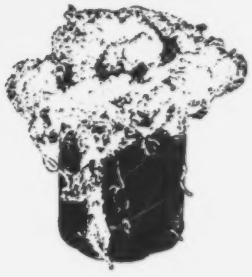
d. _____

TEST



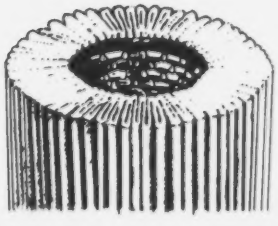
e. _____

15. Label the types of hydraulic-system filters illustrated below.

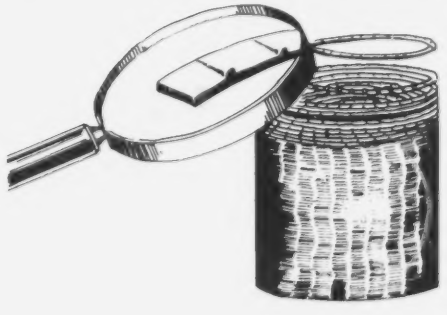


a. _____

b. _____



c. _____



d. _____

16. Name classifications of filters.

a. _____

b. _____

TEST

17. Explain why filters are used.

_____

_____

18. List seven probable causes of trouble in a hydraulic system.

a. _____

b. _____

c. _____

d. _____

e. _____

f. _____

g. _____

(NOTE: Test question 19 lists the job sheets. They are an important part of this test. If they have not been completed, check with your instructor.)

19. Demonstrate the ability to

a. Change oil in a hydraulic system.

b. Disassemble, inspect, and reassemble a directional control valve.

c. Disassemble, inspect, and reassemble a gear pump.

d. Remove and replace the packing gland on a piston rod.

HYDRAULIC SYSTEMS
UNIT I

ANSWERS TO TEST

1.

a.	10	f.	11	k.	6
b.	2	g.	7	l.	4
c.	1	h.	5	m.	12
d.	8	i.	9		
e.	13	j.	3		

2. a, b, d, e

3. a, b, d, e, g, h

4.

a.	Air vent	e.	Relief valve
b.	Lines	f.	Reservoir
c.	Cylinder (actuator)	g.	Pump
d.	Control valve		

5. a. Hydrostatic
   b. Hydrodynamic

6. a, b, c

7. a. H
   b. M

8. Description should include the following

   To regulate pressure, direction, and volume of oil flow throughout the hydraulic system

ANSWERS TO TEST

9. a. Volume control
   b. Pressure control
   c. Directional control

10. a. Piston-type
    b. Vane-type

11. a. Vane
    b. Piston
    c. Gear

12. Description should include the following

    To convert mechanical force to hydraulic fluid power

13. a. Storing energy
    b. Absorbing shock
    c. Building pressure gradually
    d. Maintaining constant pressure

14. a. Weight-loaded
    b. Bladder-type
    c. Piston
    d. Spring-loaded
    e. Diaphragm

15. a. Cotton waste
    b. Wire mesh
    c. Pleated paper
    d. Metal edge

ANSWERS TO TEST

16. a. Surface-type

    b. Depth-type

17. Explanation should include the following

    To filter out contaminants in order to keep the hydraulic fluid clean

18. Answer should include any seven of the following

    a. Broken lines

    b. Leaking lines

    c. Dirty oil

    d. Low oil in reservoir

    e. Too much oil in reservoir

    f. Defective or worn pump

    g. Defective or worn valves

    h. Leaking piston rod packings

    i. Worn or broken O-rings

    j. Defective, cross-threaded, or mismatched threads on fittings

    k. Water or contamination in system

19. Performance skills evaluated to the satisfaction of the instructor

BRAKE SYSTEMS
UNIT II

UNIT OBJECTIVE

After completing this unit, the student should be able to describe brake operation and be able to identify and recondition components of different brake systems. The student will show this knowledge by completing job sheets and unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match terms associated with brake systems to their correct definitions.
2. Describe the purposes of brakes.
3. Identify components of a standard brake system.
4. Identify components of a tandem or dual brake system.
5. Identify major components of a disc brake system.
6. Identify components of a vacuum brake system.
7. Identify components of an air brake system.
8. Identify components of an air-over-hydraulic brake system.
9. Identify parts of a standard master cylinder.
10. Identify parts of a wheel cylinder.
11. Identify parts of a standard brake assembly.
12. List types of disc brake calipers.
13. Identify parts of a floating-caliper disc brake.
14. Discuss reasons disc brakes may require power boosters.
15. Name types of energy for power boosters.
16. Describe brake operation.
17. List factors that may cause difficulties in brake adjustment.

OBJECTIVE SHEET

18. Name types of brake linings.

19. List requirements of extra-heavy-duty brake fluid.

20. Demonstrate the ability to

    a. Adjust brake shoes.

    b. Bleed the brake system.

    c. Remove, inspect, and reinstall brake drums.

    d. Remove and replace brake shoes.

    e. Remove, recondition, and reinstall a wheel cylinder.

    f. Remove, recondition, and reinstall a master cylinder on a crawler.

    g. Test the hydraulic system.

    h. Test the vacuum power booster.

    i. Repair a sliding-caliper disc brake.

    j. Check disc runout and thickness.

    k. Adjust parking brake on a crawler.

BRAKE SYSTEMS
UNIT II

SUGGESTED ACTIVITIES

I. Suggested activities

A. Obtain transparencies.

(NOTE: Transparencies are available from AGC and CIMC.)

B. Provide students with objective sheet.

C. Discuss unit and specific objectives.

D. Provide students with information and job sheets.

E. Discuss information sheet.

F. Secure materials and equipment for job sheet demonstrations.

G. Demonstrate and discuss procedures outlined in job sheets.

H. Give test.

I. Complete appropriate section of competency profiles.

(NOTE: Competency profiles are available from AGC and CIMC.)

II. Instructional materials

A. Objective sheet

B. Suggested activities

C. Information sheet

D. Transparency masters

1. TM #1 — Major Components of a Disc Brake System
2. TM #2 — Types of Disc Brake Calipers

E. Job sheets

1. Job Sheet #1 — Adjust Brake Shoes
2. Job Sheet #2 — Bleed the Brake System
3. Job Sheet #3 — Remove, Inspect, and Reinstall Brake Drums

SUGGESTED ACTIVITIES

4. Job Sheet #4 — Remove and Replace Brake Shoes

5. Job Sheet #5 — Remove, Recondition, and Reinstall a Wheel Cylinder

6. Job Sheet #6 — Remove, Recondition, and Reinstall a Master Cylinder on a Crawler

7. Job Sheet #7 — Test the Hydraulic System

8. Job Sheet #8 — Test the Vacuum Power Booster

9. Job Sheet #9 — Repair a Sliding-Caliper Disc Brake

10. Job Sheet #10 — Check Disc Runout and Thickness

11. Job Sheet #11 — Adjust Parking Brake on a Crawler

F. Test

G. Answers to test

III. Unit references

A. Armstrong, Ivan J. *Auto Mechanics,* Vol. I. Stillwater, Oklahoma: State Department of Vocational and Technical Education/Curriculum and Instructional Materials Center, 1976.

B. Departments of the Army and the Air Force. *Principles of Automotive Vehicles: TM9-8000-TO 36A-1-76.* Washington, D.C.: U.S. Government Printing Office, 1956.

C. Nichols, Herbert L., Jr. *Moving the Earth,* 3rd ed. Greenwich, Connecticut: North Castle Books, 1976.

D. *Service Manual for 450 Crawler.* C.E. Div. 9-72334, Racine, Wisconsin: JI Case, A Tenneco Company, 1978.

BRAKE SYSTEMS
UNIT II

INFORMATION SHEET

I. Terms and definitions

A. Hydraulic — Operated by the movement and force of fluid

B. Brake fluid — Special fluid used in hydraulic brake systems

(NOTE: It is important to use an extra-heavy-duty brake fluid to give maximum protection to the hydraulic system. This fluid is colored blue for identification purposes.)

C. Hydraulic cylinder — Cylinder that produces, or is controlled by, the motion of fluid

D. Bleeding the brakes — Removal of air from hydraulic brake system

E. Master cylinder — Hydraulic cylinder used to force brake fluid to individual wheel cylinders when brakes are applied

F. Brake line — High-pressure line used to carry brake fluid from master cylinder to wheel cylinders

G. Wheel cylinder — Hydraulic cylinder actuated by hydraulic pressure; forces brake lining into contact with brake drum

H. Brake shoe — Part of brake assembly to which brake lining is attached

I. Brake drum — Cast-iron or aluminum housing that rotates around brake assembly; provides a smooth surface for brake shoes to contact and exert braking action

J. Disc brakes — Brake system utilizing a caliper, which compresses brake shoes against a circular disc

K. Caliper — Device consisting of two plates that are lined with a frictional material and press against sides of a rotating wheel or disc

L. Friction — Resistance to relative movement between two bodies in contact

M. Power booster — Vacuum or hydraulic unit designed to assist operator when applying brakes

N. Manifold vacuum — Pressure lower than atmospheric pressure developed in engine intake manifold and cylinders by movement of cylinder pistons

(NOTE: This low pressure is used to operate the power booster by applying vacuum to one side of a diaphragm and atmospheric pressure to the other.)

INFORMATION SHEET

O. Outboard shoe — Shoe opposite caliper piston and outside brake disc

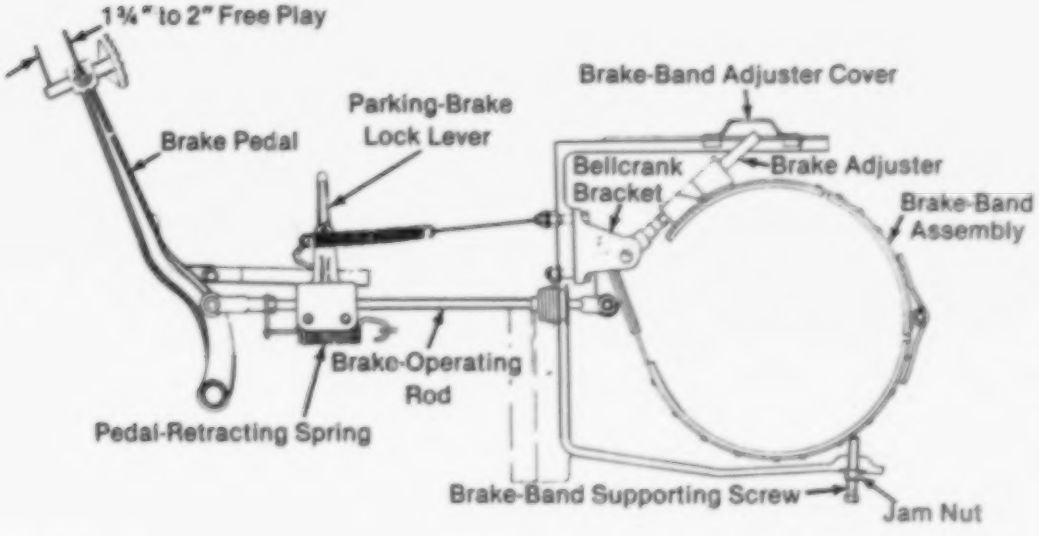
P. Inboard shoe — Shoe next to the single piston in caliper on vehicle frame side of brake disc

Q. DOT — Department of Transportation; federal agency that sets standards for safety items on motor vehicles

II. Purposes of brakes — Slowing, stopping, holding, and in some cases, steering an object (Figure 1)

EXAMPLE:

FIGURE 1

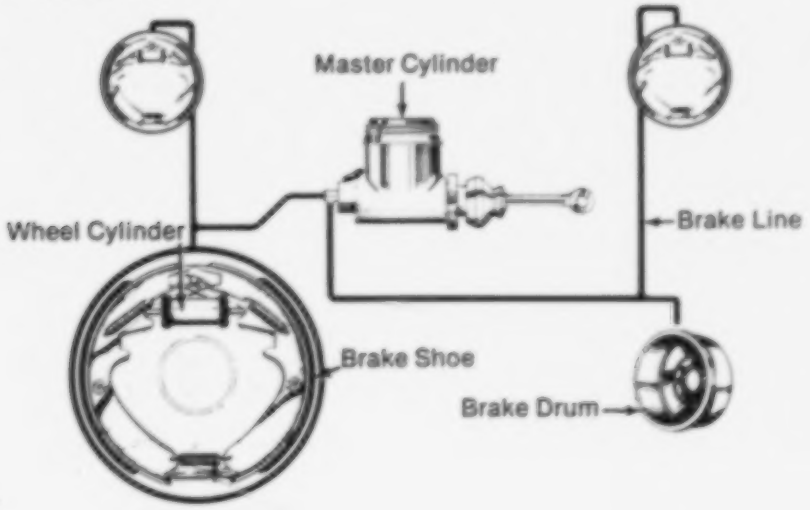


Used with permission of Fiat-Allis Construction Machinery, Inc.

INFORMATION SHEET

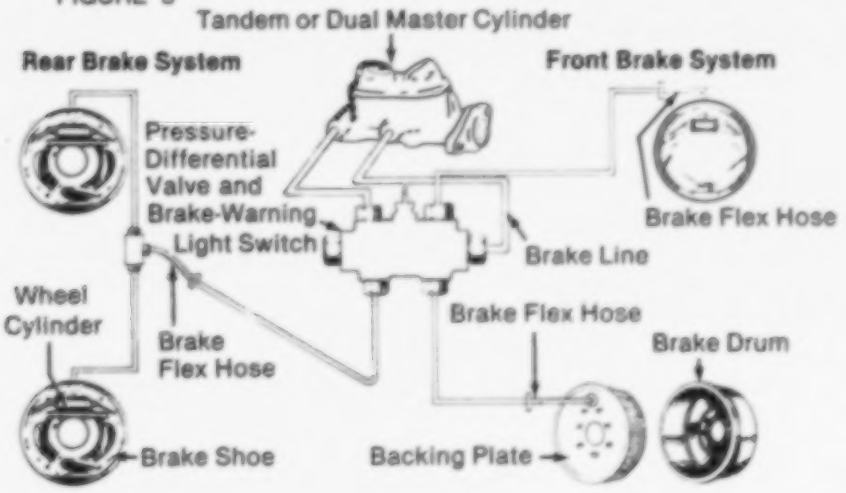
III. Components of a standard brake system (Figure 2)

FIGURE 2



IV. Components of a tandem or dual brake system (Figure 3)

FIGURE 3



INFORMATION SHEET

V. Major components of a disc brake system (Transparency #1)

(NOTE: The pressure-differential, proportioning, and metering valves are usually contained in one housing and are known as a *combination valve*.)

A. Master cylinder

B. Pressure-differential valve

C. Proportioning valve

D. Metering valve

E. Front disc or rotor assembly

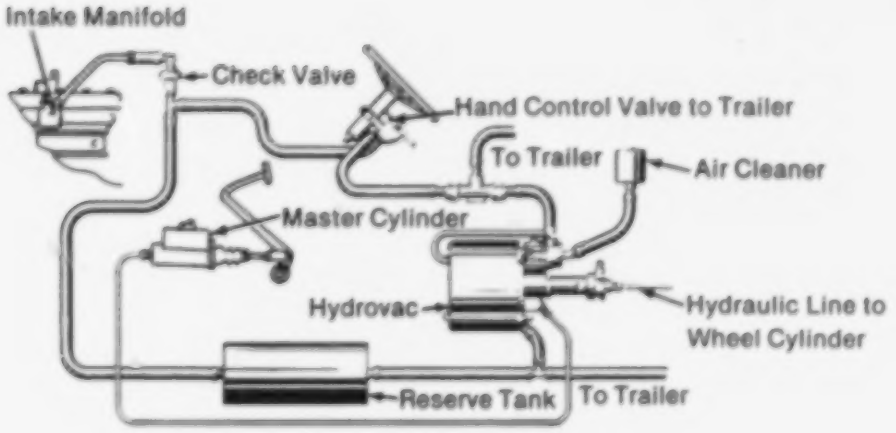
F. Caliper assembly

G. Power booster

H. Rear drum or disc brake assembly

VI. Components of a vacuum brake system (Figure 4)

FIGURE 4

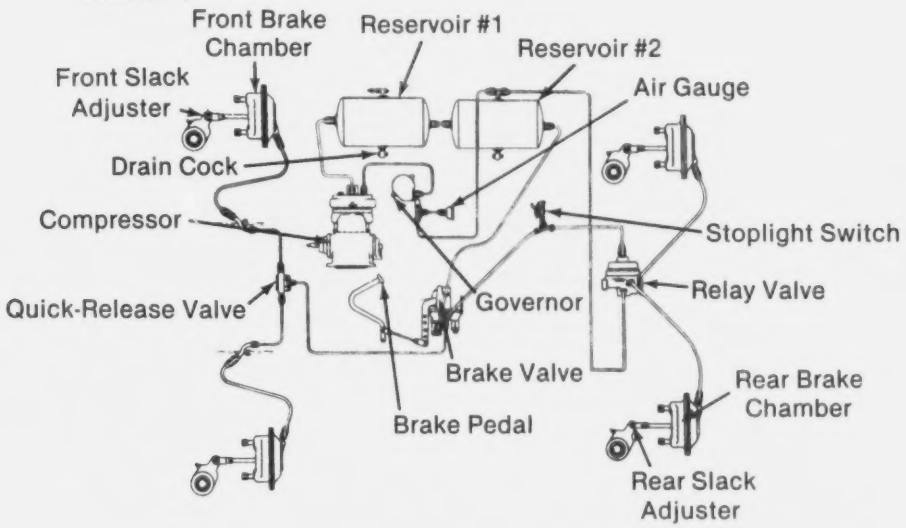


Adapted with permission of The Bendix Corporation.

INFORMATION SHEET

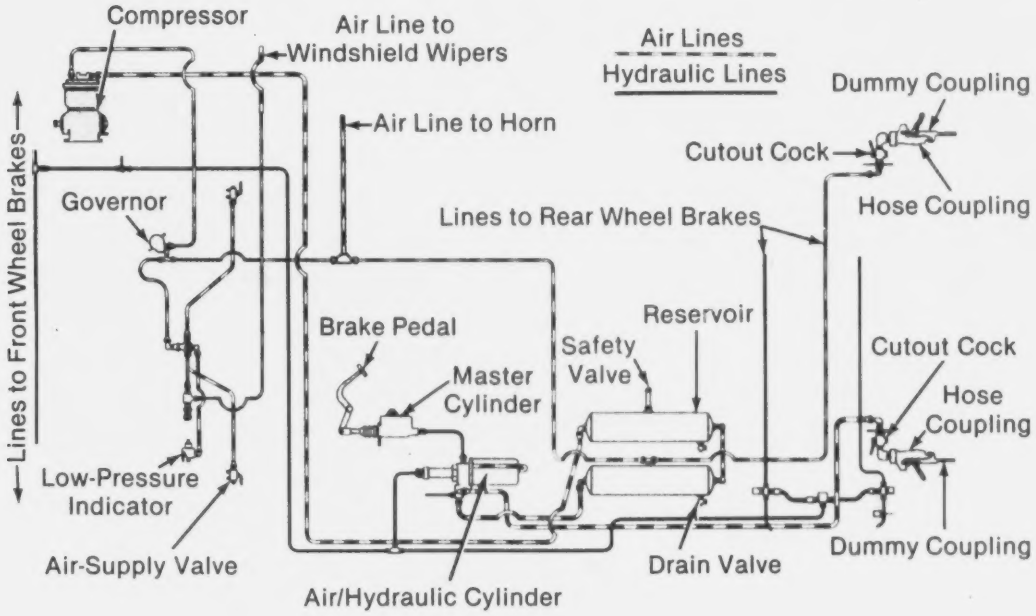
VII. Components of an air brake system (Figure 5)

FIGURE 5



VIII. Components of an air-over-hydraulic brake system (Figure 6)

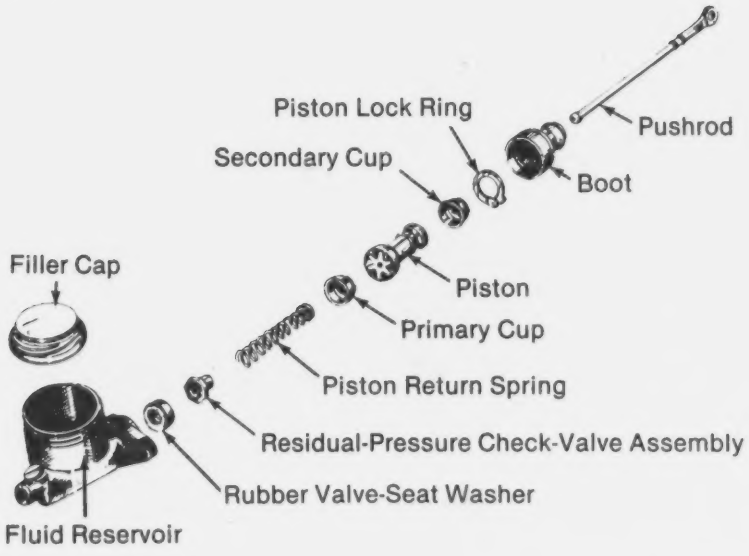
FIGURE 6



INFORMATION SHEET

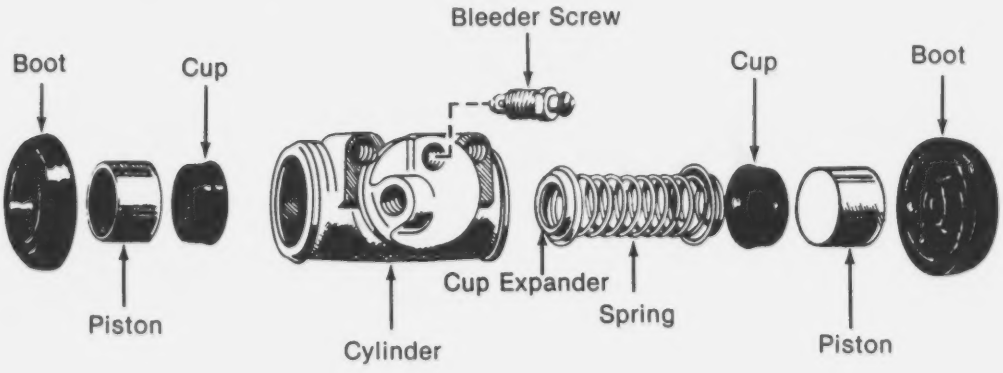
IX. Parts of a standard master cylinder (Figure 7)

FIGURE 7



X. Parts of a wheel cylinder (Figure 8)

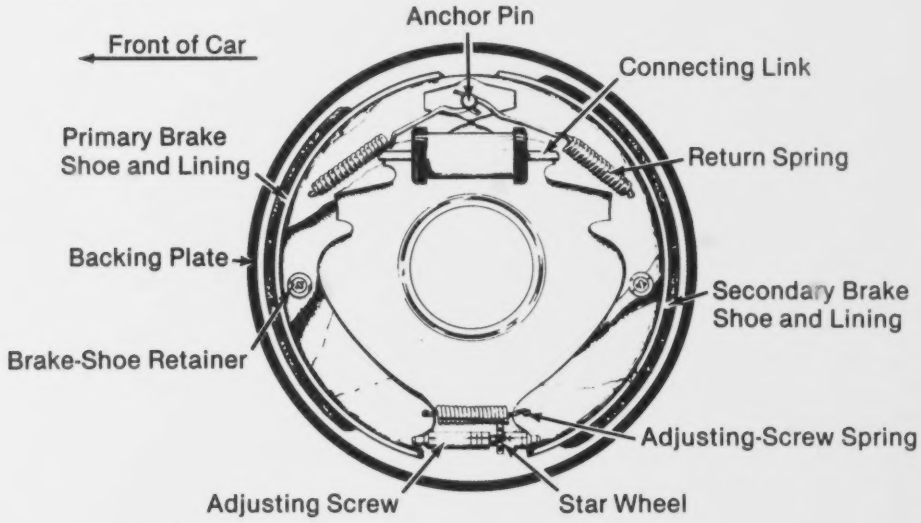
FIGURE 8



INFORMATION SHEET

XI. Parts of a standard brake assembly (Figure 9)

FIGURE 9



XII. Types of disc brake calipers (Transparency #2)

A. Fixed

(NOTE: The multipiston caliper is bolted directly to the steering knuckle.)

B. Floating

(NOTE: The single-piston caliper is supported by and floats on two mounting bolts; the braking force is exerted against the caliper adapter.)

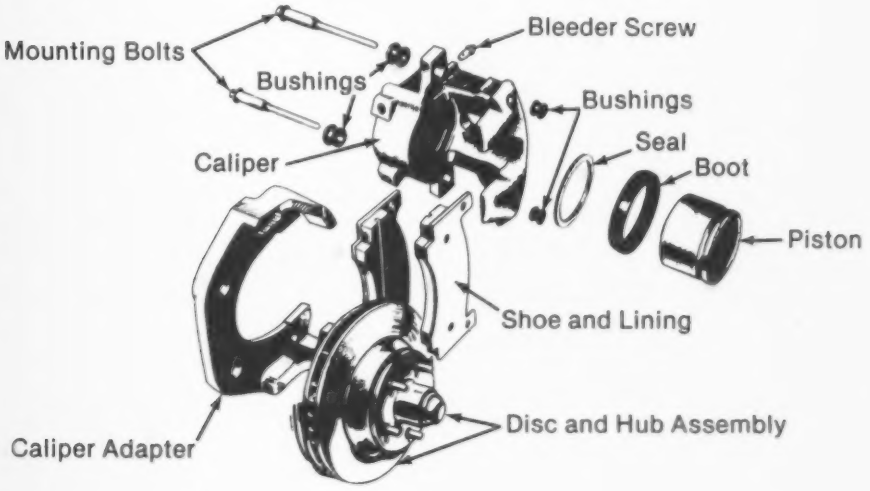
C. Sliding

(NOTE: The single-piston caliper is supported by and free to slide from side to side on machined ways in the caliper adapter, which also receives the braking force.)

INFORMATION SHEET

XIII. Parts of a floating-caliper disc brake (Figure 10)

FIGURE 10



XIV. Reasons disc brakes may require power boosters

A. Disc brake shoes have no servo action

(NOTE: Disc brake shoes require four to five times more applied pressure than drum brakes.)

B. Disc shoe linings have less contact surface than drum brake shoes

XV. Types of energy for power boosters

A. Vacuum

(NOTE: Vacuum is obtained from the engine at the intake-manifold connection.)

B. Hydraulic

(NOTE: Hydraulic pressure is obtained from the power-steering pump.)

XVI. Brake operation

A. Brake pedal depressed

1. Master cylinder forces brake fluid through check valve into brake lines

INFORMATION SHEET

2. Brake fluid travels through brake lines to wheel cylinders

3. Force of brake fluid by master cylinder causes wheel-cylinder cups and pistons to move outward

4. Movement caused by wheel-cylinder pistons forces brake shoe and lining to make contact with brake drum

5. Force of fluid and contact of brake lining with brake drum cause vehicle to slow or stop

B. Brake pedal released — Return springs pull brake shoes back to stop position, forcing brake fluid to return to master-cylinder reservoir

XVII. Factors that may cause difficulties in brake adjustment

A. Broken disc or shoes

B. Broken linings

C. Cracked linings

D. Uneven linings

E. Foreign objects between lining and drums

F. Warped shoes or bands

G. Bent shoes or bands

H. Linkage difficulties

XVIII. Types of brake linings

A. Molded asbestos

(NOTE: These linings may include metals such as zinc, tin, lead, and copper; and organic compounds such as rubber, resin, drying oils, and ground cashew shells.)

B. Woven

(NOTE: Lining consists of asbestos, metal threads, organic compounds, and metals.)

XIX. Requirements of extra-heavy-duty brake fluid

(NOTE: Fluid used in disc brake systems must conform to DOT Code #3 as a minimum-quality fluid.)

A. Must have high boiling point

(NOTE: Fluid must not vaporize at temperatures lower than 550°F.)

INFORMATION SHEET

B. Must have low freezing point

(NOTE: Fluid must not freeze at lowest operating temperatures.)

C. Must be of consistent viscosity

(NOTE: Fluid must be free flowing at all temperatures.)

D. Must be noncorrosive

(NOTE: Fluid must not attack metal or rubber parts.)

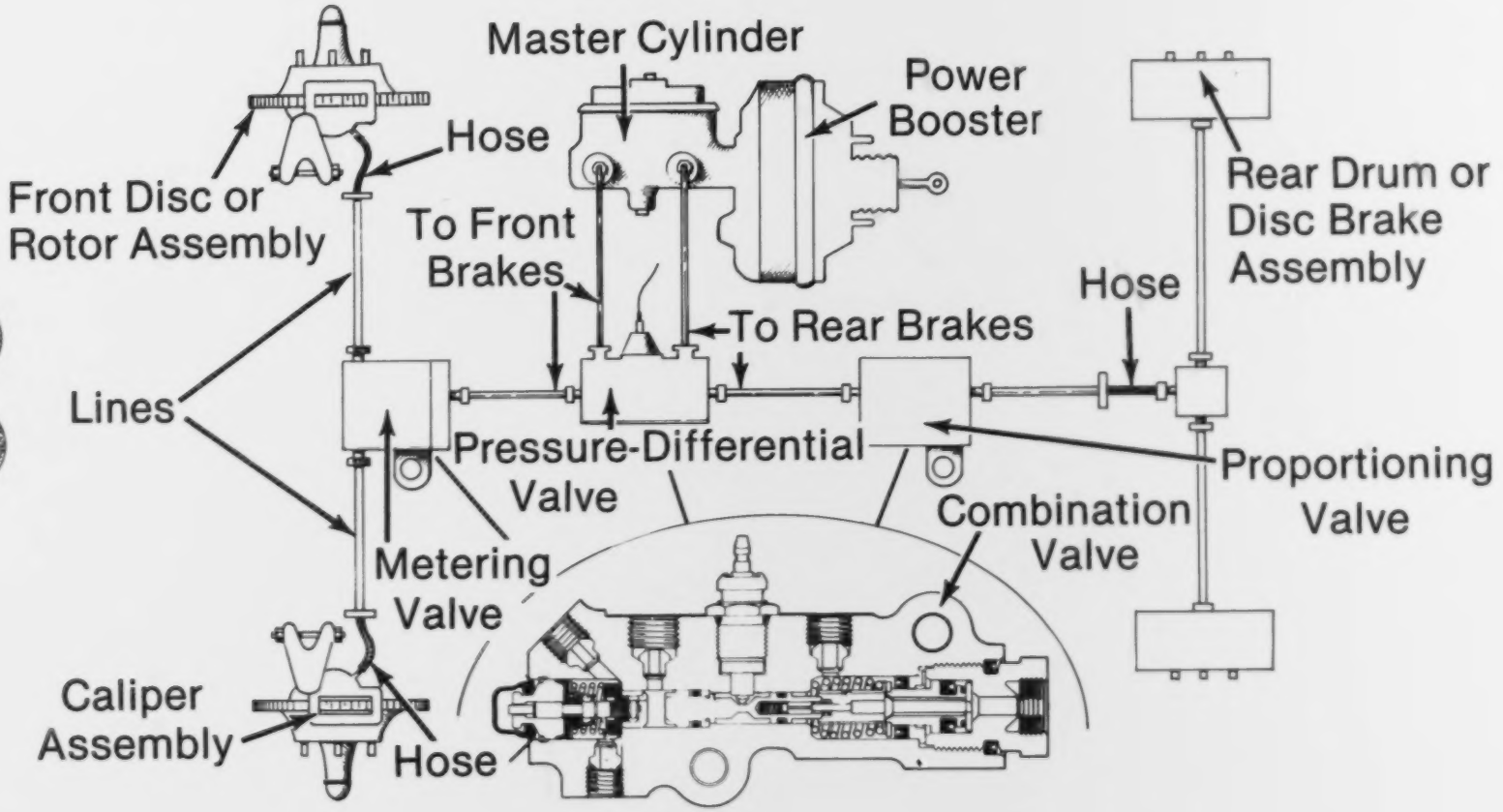
E. Must be water tolerant

(NOTE: Fluid must be able to absorb and retain moisture that enters the system.)

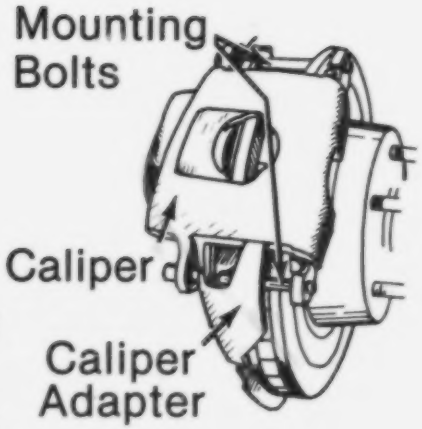
F. Must possess lubricating ability

(NOTE: Fluid must lubricate pistons and seals to reduce wear and internal friction.)

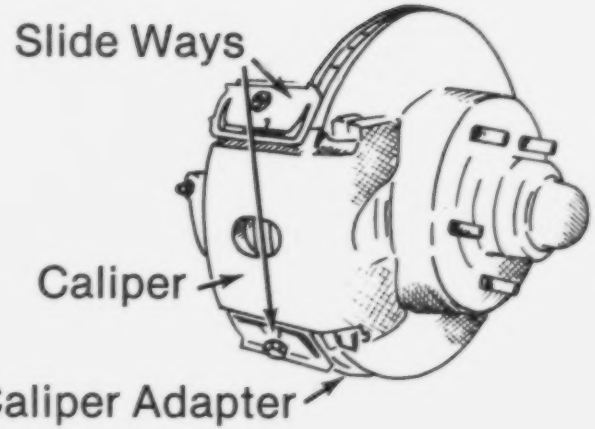
Major Components of a Disc Brake System



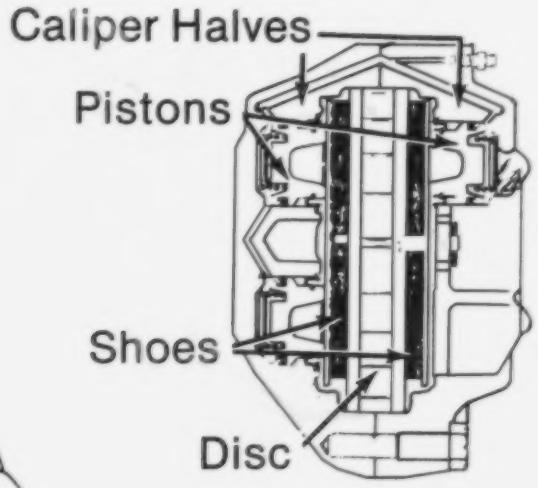
Types of Disc Brake Calipers



Floating



Sliding



Fixed

BRAKE SYSTEMS
UNIT II

JOB SHEET #1 — ADJUST BRAKE SHOES

I. Equipment and materials

A. Brake adjustment tool

B. Long, thin-blade screwdriver

C. Floor jack

D. Jack stands

E. Drum-to-shoe gauge

II. Procedure for minor adjustment on manually adjusted brakes

A. Raise vehicle and support on jack stands

B. Pull off a wheel and brake drum to inspect brake lining

C. Make sure parking-brake cables are fully released

D. Remove cover from brake-adjuster access hole

E. Insert brake (star wheel) adjustment tool through access hole and against star wheel

F. Move handle of adjustment tool upward to tighten and expand brake shoes (Figure 11)

FIGURE 11

Manually Adjusted Brake

G. Adjust brake shoes until both hands are required to rotate drum

JOB SHEET #1

H. Back off star wheel ten to sixteen clicks

(NOTE: The adjusting tool handle is moved downward to back off the brake shoes.)

I. Make sure brake drum turns freely after backing off brake shoes

(NOTE: Check pedal height and feel to determine if other service is required.)

J. Reinstall brake-adjuster access-hole covers

K. Remove jack stands

L. Lower vehicle to floor

M. Check brake fluid

N. Clean work area; clean and put away all equipment and materials

BRAKE SYSTEMS
UNIT II

JOB SHEET #2 — BLEED THE BRAKE SYSTEM

I. Equipment and materials

A. 1/4- and 1/2-inch combination wrenches

B. 10-inch-long adjustable wrench

C. Pressure-tank brake-bleeding equipment

D. Brake fluid

E. Clean, clear container

F. Bleeder hose

G. Brake-bleeder wrenches as required

H. Appropriate service manual

I. Six-point box wrench

J. Person to assist you

II. Procedure for manually bleeding a hydraulic system

A. Remove cap from master cylinder; fill master cylinder with clean, fresh brake fluid

(CAUTION: Do not allow the master-cylinder reservoir to become empty of fluid during the bleeding process.)

(NOTE: Use care when handling brake fluid.)

B. Attach a bleeder hose to bleeder screw of wheel cylinder

(NOTE: Bleed right-rear wheel cylinder first on single-cylinder master cylinders, but treat tandem master-cylinder-type as two separate systems by bleeding either the front or rear brakes first.)

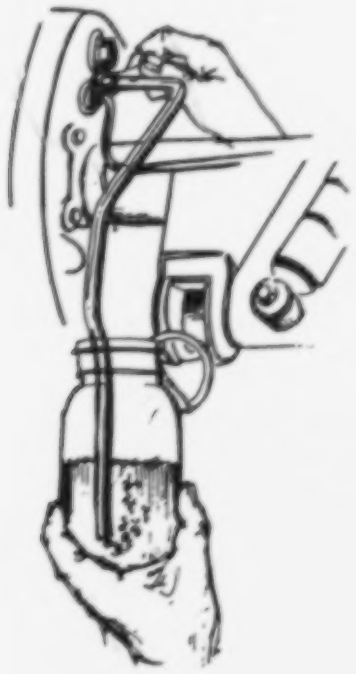
JOB SHEET #2

C. Place loose end of bleeder hose in clear container partially filled with brake fluid

(CAUTION: Do not reuse the fluid from the container; that fluid is contaminated.)

(NOTE: See Figure 12. The end of the bleeder hose must be completely submerged.)

FIGURE 12



D. Open wheel-cylinder bleeder screw approximately three-fourths of a turn

(NOTE: Use six-point box wrench on bleeder screw.)

E. Have a helper slowly depress brake pedal until it reaches end of travel

F. Close wheel-cylinder bleeder screw

G. Have helper allow brake pedal to return slowly to fully released position

H. Repeat this operation until brake fluid flows from end of bleeder hose in a solid stream that is completely free of air bubbles

JOB SHEET #2

I. Close wheel-cylinder bleeder screw tightly

J. Remove bleeder hose from wheel-cylinder bleeder screw

K. Refill master cylinder

L. Repeat bleeding operation on remaining wheel cylinders until complete

M. Refill master-cylinder reservoir to proper level with clean, fresh brake fluid

N. Reinstall cap

O. Clean work area; clean and put away all tools and equipment

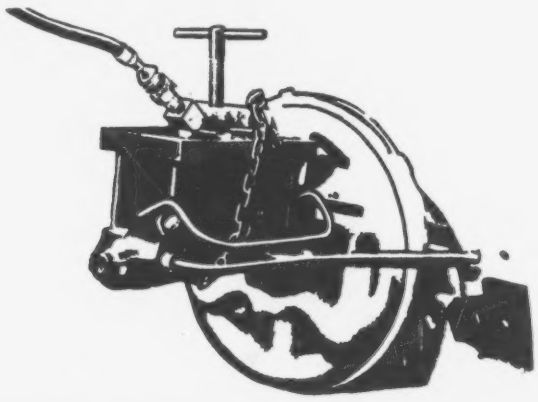
III. Procedure for pressure bleeding a hydraulic system

A. Remove cap from master cylinder; fill master cylinder with clean, fresh brake fluid

(NOTE: Use care when handling brake fluid.)

B. Install special bleeding adapter to master cylinder (Figure 13)

FIGURE 13



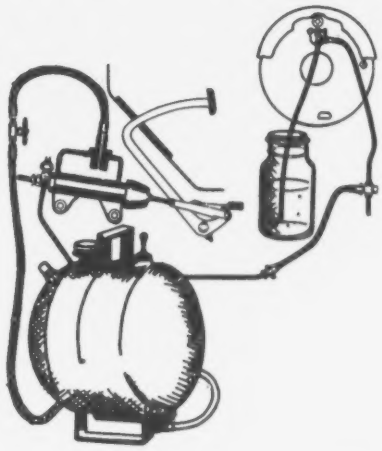
C. Make sure that pressure bleeder tank is at least one-third full of fluid

JOB SHEET #2

D. Adjust pressure from 25 psi to 35 psi (Figure 14)

(NOTE: Follow equipment manufacturer's specifications on bleeder operation.)

FIGURE 14



E. Connect bleeder tank hose to adapter at master cylinder

F. Connect one end of bleeder hose to wheel-cylinder bleeder screw

G. Place loose end of bleeder hose in a clear container partially filled with brake fluid

(CAUTION: Do not reuse the fluid from the container; that fluid is contaminated.)

(NOTE: The end of the bleeder hose must be completely submerged.)

H. Open wheel-cylinder bleeder screw approximately three-fourths of a turn

(NOTE: Use six-point box wrench on bleeder screw.)

I. Allow fluid to flow into container until fluid flows in a solid stream that is completely free of air bubbles

J. Close wheel-cylinder bleeder screw tightly

K. Remove bleeder hose from wheel-cylinder bleeder screw and repeat procedures for each of the remaining wheel cylinders

JOB SHEET #2

L. Disconnect brake pressure bleeder

M. Remove master-cylinder adapter

N. Check master-cylinder brake fluid level

O. Reinstall cap

P. Clean work area; clean and put away all equipment and materials

BRAKE SYSTEMS
UNIT II

JOB SHEET #3 — REMOVE, INSPECT, AND REINSTALL BRAKE DRUMS

I. Equipment and materials

- A. Floor jack
- B. Jack stands
- C. Pliers
- D. Channel lock pliers
- E. Diagonal cutting pliers
- F. Lug wrench
- G. Torque wrench
- H. Sockets to fit lug bolts
- I. Brake adjustment tools
- J. Rubber hammer
- K. Screwdriver
- L. Shop towels
- M. Creeper
- N. Appropriate service manual

II. Procedure

- A. Raise vehicle and support on jack stands
- B. Remove wheels

  (NOTE: Some vehicles have left-hand lug bolts; use care to avoid twisting them off.)
- C. Remove grease cap

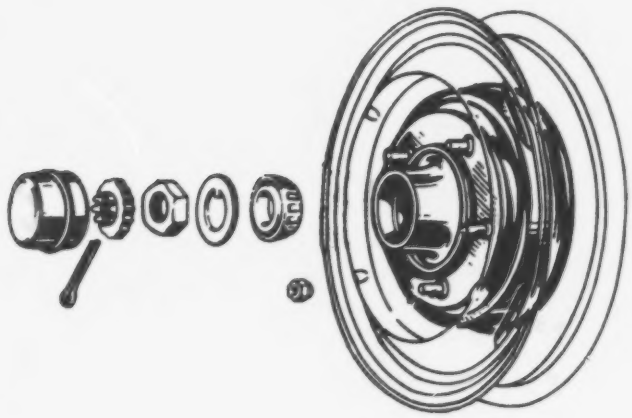
  (NOTE: See Figure 15 on the following page.)
- D. Remove cotter pin and spindle nut
- E. Remove outer washer and wheel bearing

JOB SHEET #3

F. Remove front brake drum (Figure 15)

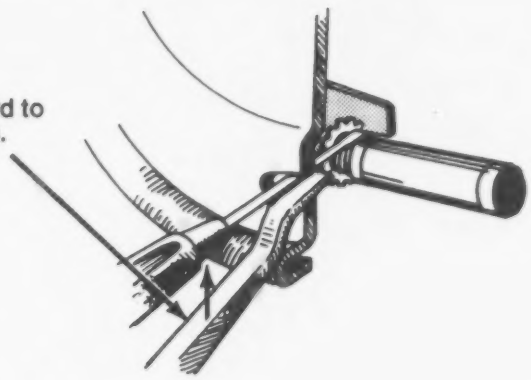
(CAUTION: Protect the wheel bearings from dirt; use care to avoid dropping the brake drum.)

FIGURE 15



(NOTE: It may be necessary to back off the brake shoe adjustment to allow the brake drum to be removed; see Figure 16.)

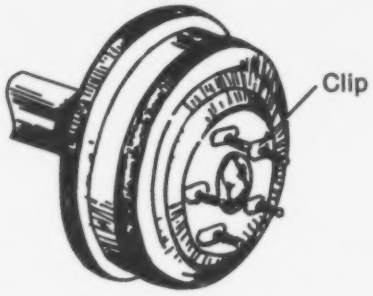
FIGURE 16



JOB SHEET #3

G. Remove metal clip retainers on rear brake drums (Figure 17)

FIGURE 17



H. Back off brake shoe adjustment as required

I. Remove rear brake drums

J. Inspect brake shoes and determine if replacement is necessary

(NOTE: Consult the instructor.)

K. Clean brake drums

L. Inspect brake drums for cracks, scores, or any defect on the friction surface; check for wear, taper, or out-of-round conditions

M. Service brake drums as required

N. Perform other brake service as required

O. Reinstall front brake drums

(NOTE: Make sure that the wheel bearings and seals are properly lubricated and in place.)

P. Install outer wheel bearing, washer, and spindle nut; adjust according to manufacturer's specifications

Q. Install nut lock, if used, and a new cotter pin

R. Install grease cap

S. Reinstall rear brake drums

T. Install drum retainer clips

JOB SHEET #3

U. Install wheels and tires

V. Torque lug bolts in sequence according to manufacturer's specifications

(CAUTION: Do not overtighten lugs; brake drums may be damaged.)

W. Make additional brake adjustments as required

X. Remove jack stands

Y. Lower vehicle to floor

Z. Clean work area; clean and put away all equipment and materials

BRAKE SYSTEMS
UNIT II

JOB SHEET #4 — REMOVE AND REPLACE BRAKE SHOES

I. Equipment and materials

A. Floor jack

B. Jack stands

C. Brake-shoe removal tools

D. Channel lock pliers

E. Diagonal cutting pliers

F. Pliers

G. Rubber hammer

H. Screwdriver

I. Wheel-bearing and high-temperature lubricants

J. Shop towels

K. Lug wrench

L. Torque wrench

M. 3/8- and 5/8-inch combination wrenches

N. Four wheel-cylinder clamps

O. Four sets of brake shoes

P. Appropriate service manual

II. Procedure

(NOTE: Replace brake shoes or brake linings if linings are soaked with oil, brake fluid, or grease; if linings are burned; if rivets are loose; if linings are worn excessively; or if brake shoes are warped or defective.)

A. Raise vehicle and support on jack stands

B. Remove wheels

(NOTE: Some vehicles have left-hand lug bolts; use care to avoid twisting them off.)

JOB SHEET #4

C. Remove brake drums

(NOTE: Blow loose dirt from brake lining with compressed air.)

D. Install wheel-cylinder clamps on wheel cylinders to prevent fluid leakage (Figure 18)

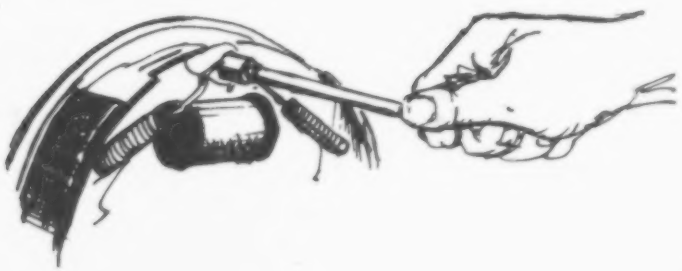
FIGURE 18

E. Remove brake shoes

1. Remove brake-shoe return springs (Figure 19)

(NOTE: Notice the color, type, and location of the brake-shoe springs so that each will be replaced in its correct position. Avoid bending spring hook.)

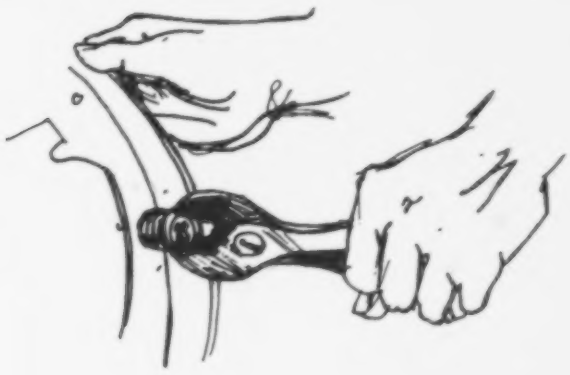
FIGURE 19



JOB SHEET #4

2. Remove brake-shoe retaining or hold-down parts (Figure 20)

FIGURE 20



3. Spread anchor ends of the brake shoes and disengage from the wheel-cylinder struts (Figure 21)

FIGURE 21

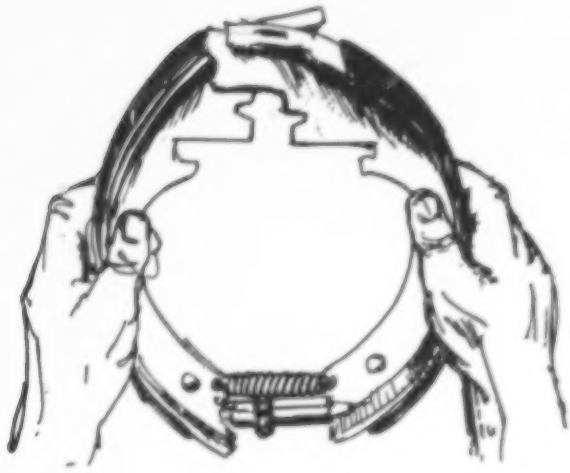
JOB SHEET #4

4. Remove brake-shoe assembly from backing plate

   (NOTE: If brake shoes are to be reused, mark them so that they can be replaced in the same position.)

5. Overlap anchor end of shoes to relieve spring tension (Figure 22)

FIGURE 22



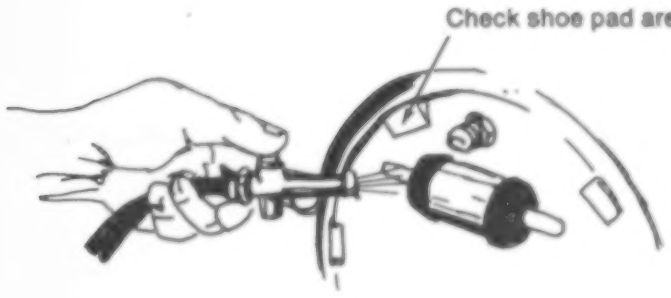
6. Unhook and remove brake-shoe adjusting-screw spring and adjusting-screw assembly

F. Clean and inspect parts

1. Clean backing plate, struts, levers, and all metal parts to be reused

   (NOTE: Blow off loose dirt with compressed air; see Figure 23.)

FIGURE 23



JOB SHEET #4

2. Check backing plates to make sure that they are free of corrosion or other surface defects and that shoe pad areas are smooth

3. Check for oil leakage past wheel-bearing seals on rear wheels

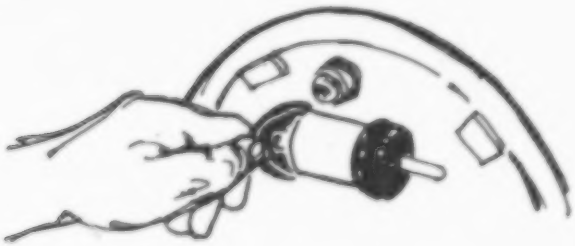
   (NOTE: Such leakage will indicate the need for additional service work.)

4. Check all wheel cylinders for cracked, cut, or torn boots

5. Pull back lower edge of boot carefully to check for fluid leakage (Figure 24)

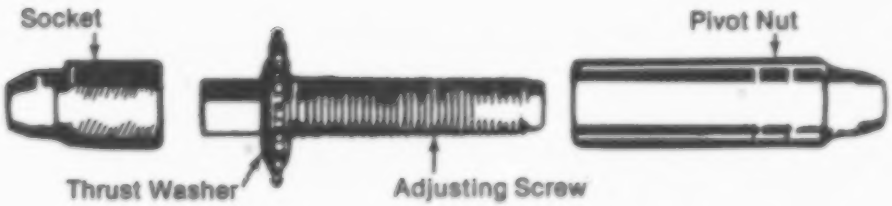
   (NOTE: Overhaul or replace cylinder if any fluid is present or if cylinders are defective in any way.)

FIGURE 24



6. Disassemble adjusting-screw assembly (Figure 25)

FIGURE 25



7. Clean parts

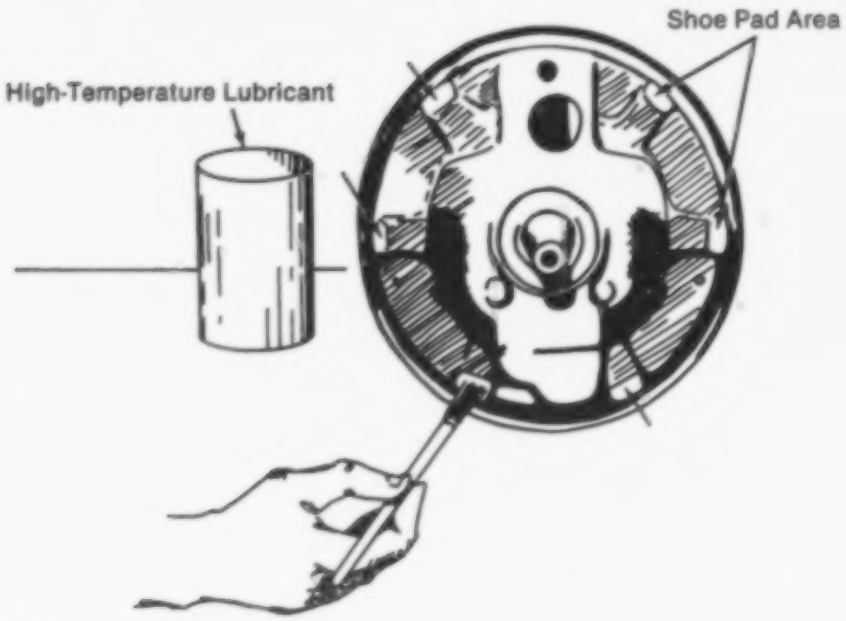
8. Lubricate adjusting-screw threads with high-temperature lubricant

9. Reassemble parts

10. Turn adjusting screw in as far as it will go

11. Apply a thin coat of lubricant to raised shoe pads on backing plate (Figure 26)

FIGURE 26



G. Replace brake shoes

1. Lay replacement brake shoes in same position as they are to be installed

(CAUTION: Make sure all parts are kept clean during reassembly. This is a must for safe brake work.)

(NOTE: The primary shoe [the shoe with the shortest lining] goes to the front of the vehicle.)

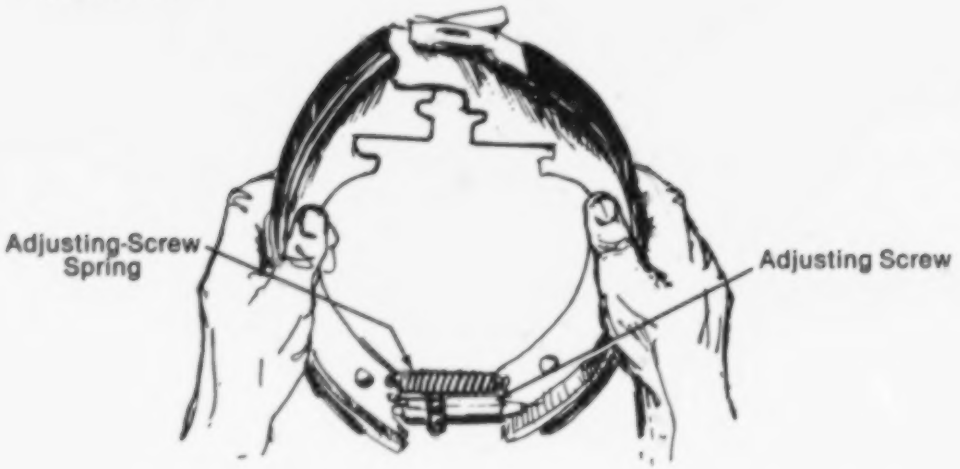
2. Hook brake-shoe adjusting-screw spring between shoes

JOB SHEET #4

3. Overlap anchor ends of shoes; install adjusting-screw assembly between shoes (Figure 27)

   (NOTE: Make sure the adjusting-screw assembly is installed to align with the adjusting slot in the backing plate.)

FIGURE 27

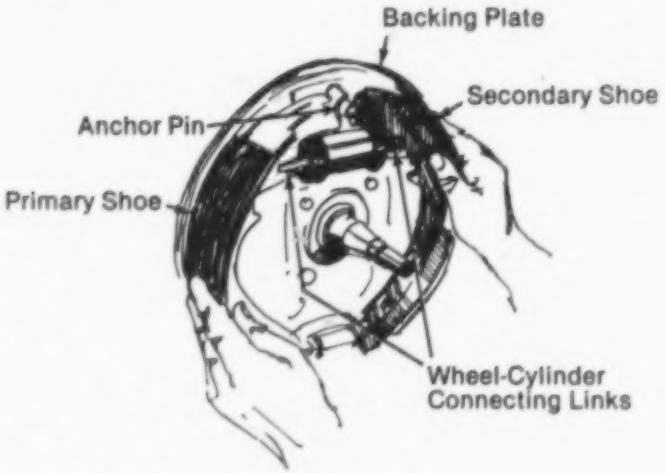


4. Spread brake-shoe anchor ends to retain adjusting screw and spring

5. Position brake-shoe assemblies on backing plate so that shoes engage wheel-cylinder connecting links (Figure 28)

   (NOTE: Make sure that the primary brake shoe is positioned toward the front of the vehicle and that the adjusting-screw assembly is installed correctly.)

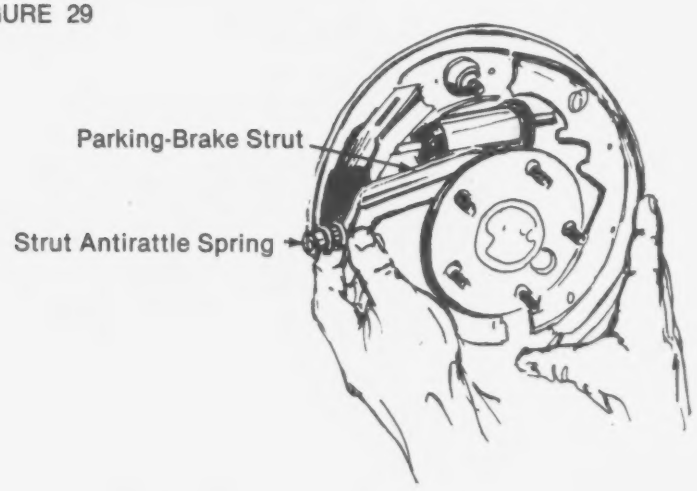
FIGURE 28



JOB SHEET #4

6. Spread shoes slightly and install parking-brake strut and spring on rear brakes (Figure 29)

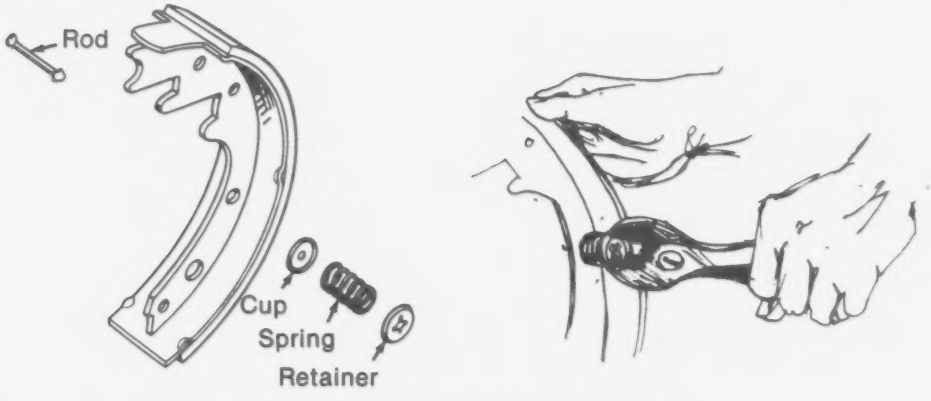
FIGURE 29



7. Reinstall brake-shoe retaining or hold-down parts (Figure 30)

(NOTE: Install self-adjusting mechanism if required.)

FIGURE 30



8. Reinstall brake-shoe return springs

(NOTE: Make sure the brake-shoe return springs are reinstalled correctly and the anchor end of spring is properly formed.)

9. Grasp brake-shoe assembly and move it back and forth slightly to make sure all parts are in place and correctly installed

(NOTE: Make *preliminary* brake-shoe adjustment on *self-adjusting* brakes before installing brake drum.)

JOB SHEET #4

H. Reinstall front brake drums

(NOTE: Make sure drums are clean and have received the necessary service.)

I. Adjust front wheel bearings

J. Install nut lock and new cotter pin

K. Install grease cap and hubcap

L. Reinstall rear brake drums

(NOTE: Make sure drums are clean and have received the necessary service.)

M. Reinstall rear drum retainer clips as required

N. Reinstall all wheels and tires

O. Torque lug bolts in sequence according to manufacturer's specifications

P. Adjust all brakes

Q. Bleed brake system if required

R. Check brake pedal height and feel

S. Remove jack stands

T. Lower vehicle to floor

U. Clean work area; clean and put away all tools and equipment

V. Road test vehicle

(NOTE: Instructor must accompany you on road test.)

BRAKE SYSTEMS
UNIT II

JOB SHEET #5 — REMOVE, RECONDITION, AND REINSTALL A WHEEL CYLINDER

I. Equipment and materials

A. 5/16- and 3/4-inch combination wrenches

B. Brake-shoe removal tools

C. Brake fluid

D. Brake cylinder hone

E. Lug wrench

F. Channel lock pliers

G. Diagonal side-cutting pliers

H. 7/16- and 9/16-inch sockets with 3/8-inch drive

I. Ratchet with 3/8-inch drive

J. Shop towels

K. Crocus cloth

L. 1/4- and 7/16-inch six-point sockets with 3/8-inch drive

M. Electric drill

N. Floor jack

O. Jack stands

P. 3/8- and 5/8-inch tubing wrenches

Q. Torque wrench

R. Brake-bleeding tools as required

S. Appropriate service manual

II. Procedure

A. Raise vehicle and support on jack stands

JOB SHEET #5

B. Remove tire and brake drum assembly

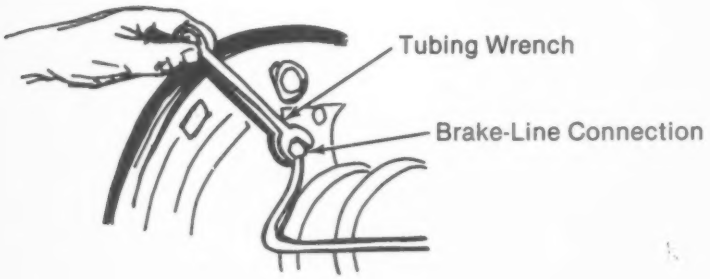
C. Remove brake shoes

D. Disconnect brake line or hose from wheel cylinder (Figure 31)

(CAUTION: Use care to prevent twisting the line or connection. Disconnect hoses at the frame connection first.)

(NOTE: Cover the end of the hose or tube to keep dirt out.)

FIGURE 31

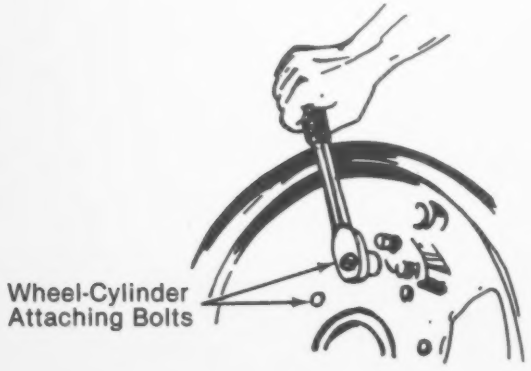


E. Inspect brake hoses

(NOTE: Replace hose if its cover is cracked or frayed.)

F. Remove wheel-cylinder attaching bolts (Figure 32)

FIGURE 32



G. Remove wheel cylinder from backing plate

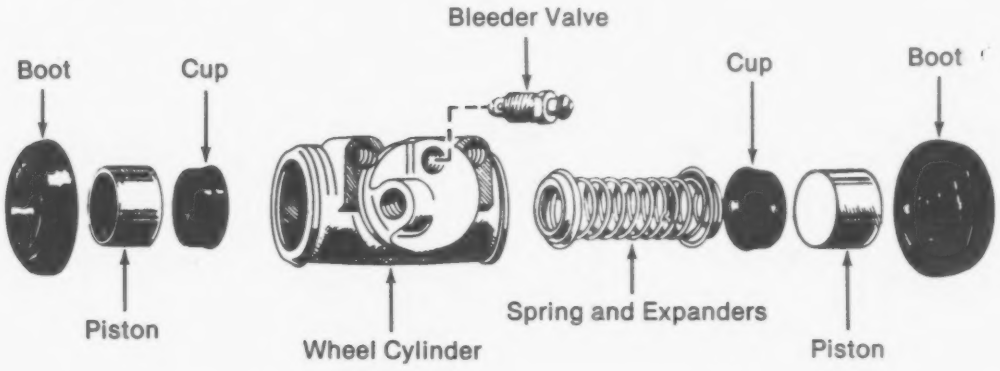
JOB SHEET #5

H. Disassemble wheel cylinder (See Figure 33)

1. Remove wheel-cylinder links if used
2. Remove wheel-cylinder boots
3. Push out pistons, cups, and spring expanders
4. Remove bleeder screw from cylinder

(NOTE: Use six-point socket or box wrench for removal.)

FIGURE 33



I. Clean and service wheel cylinder

1. Clean all reusable metal parts

(CAUTION: Always use clean brake fluid to clean any wheel-cylinder parts. Never use mineral-based cleaning solvents such as gasoline, kerosene, carbon tetrachloride, acetone, or paint thinner. These solvents deteriorate rubber parts.)

2. Inspect pistons for scratches, scoring, or corrosion
3. Inspect bleeder valve for defective threads or dirt
4. Inspect wheel-cylinder bore
5. Polish discolored or stained areas with crocus cloth by revolving cylinder on cloth-covered finger

(NOTE: If cylinder walls have deep scratches or scoring, walls will have to be reconditioned with a cylinder hone.)

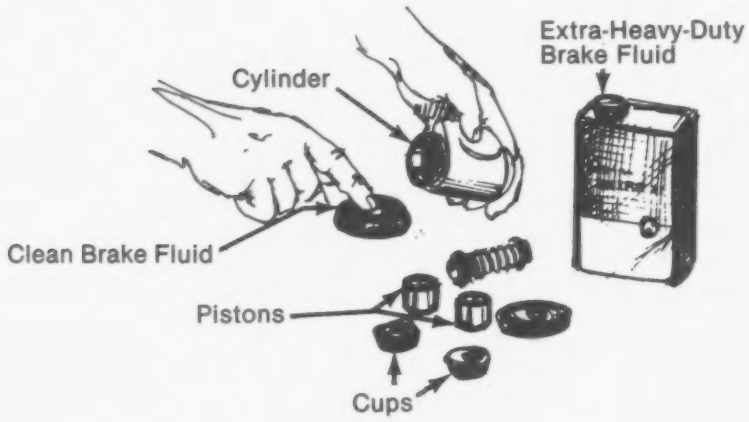
(CAUTION: Do not increase cylinder bore more than 0.002 inch. Replace any cylinder that requires honing beyond the 0.002-inch limit. See manufacturer's recommendations.)

JOB SHEET #5

J. Reassemble wheel cylinder

1. Coat cups, pistons, and cylinder bore with clean brake fluid before reassembly (Figure 34)

FIGURE 34



2. Install expanders on spring as required
3. Install spring and attached expanders into wheel cylinder

   (NOTE: Use care not to scratch the cylinder bore with the spring or expanders.)

4. Install wheel-cylinder cups with lip toward center of cylinder

   (NOTE: Use care not to damage cup lips during installation.)

5. Install wheel-cylinder pistons with flat end toward center of cylinder
6. Install wheel-cylinder boots
7. Install cylinder links

K. Install wheel cylinder on backing plate

L. Torque bolts or anchor pin according to manufacturer's specifications

M. Reinstall brake line or hose to wheel cylinder

(NOTE: Use caution to avoid cross threading.)

N. Reinstall brake-shoe assembly

JOB SHEET #5

O. Reinstall brake drum

P. Reinstall wheels and tires

Q. Adjust brake shoes as required

R. Bleed hydraulic system if required

S. Remove jack stands

T. Lower vehicle to floor

U. Clean work area; clean and put away all equipment and materials

V. Road test vehicle

(NOTE: Instructor must accompany you on road test.)

BRAKE SYSTEMS
UNIT II

JOB SHEET #6 — REMOVE, RECONDITION, AND REINSTALL A MASTER CYLINDER ON A CRAWLER

I. Equipment and materials

- A. Basic tool kit
- B. Brake fluid
- C. Brake cylinder hone (fine grit)
- D. Reconditioning kit
- E. Tubing wrenches
- F. Brake-bleeding tools as required
- G. Snap-ring pliers
- H. Warm water
- I. Detergent
- J. Appropriate service manual

II. Procedure

- A. Remove front and rear floor plates
- B. Disconnect master-cylinder pushrod from brake pedal if necessary (Figure 35)

FIGURE 35

JOB SHEET #6

C. Disconnect hydraulic line at master cylinder

(NOTE: Use a backup wrench as required to avoid twisting the hydraulic line.)

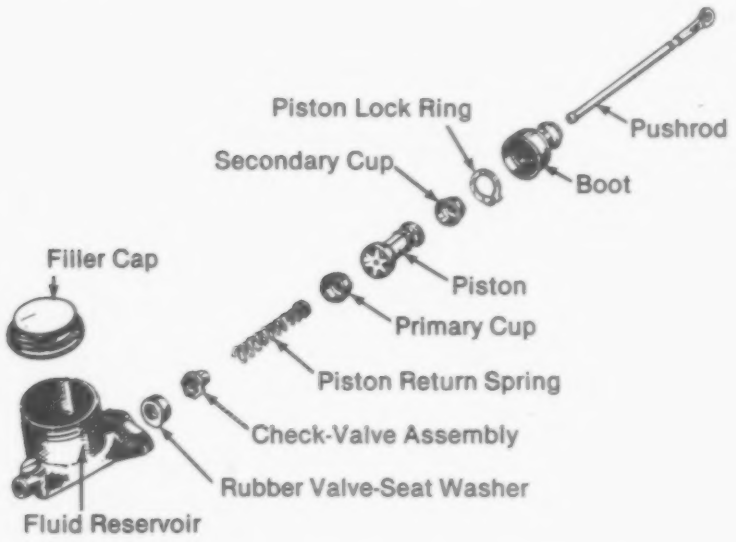
D. Plug disconnected line to keep dirt out

E. Remove bolts that hold master cylinder in place

F. Lift cylinder out of crawler

G. Disassemble master cylinder (Figure 36)

FIGURE 36



1. Brush off external dirt before disassembly
2. Remove filler cap and gasket
3. Pour out any brake fluid that remains in cylinder or reservoir
4. Remove pushrod and boot to expose piston retaining ring (piston lock ring)
5. Remove piston retaining ring from master-cylinder bore
6. Remove piston
7. Remove primary cup, spring, and check-valve assembly from bore of cylinder
8. Remove rubber valve-seat washer from cylinder bore

JOB SHEET #6

H. Clean and inspect master-cylinder parts

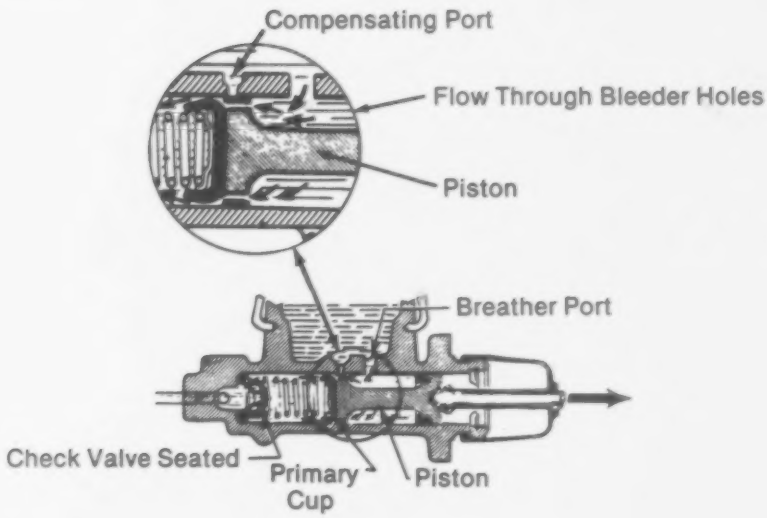
1. Clean all parts thoroughly with warm water and detergent
2. Inspect master-cylinder body for cracks, scores, and scratches
3. Recondition master-cylinder bore with a fine-grit cylinder hone

(CAUTION: Do not increase cylinder bore more than 0.002 inch.)

4. Rinse cylinder with warm water and detergent
5. Clean the compensating port and breather port (Figure 37)

(CAUTION: Do not enlarge the compensating port while cleaning it.)

FIGURE 37



6. Check piston, spring, check valve, and seats for reusable condition and replace as necessary, using reconditioning kit
7. Check filler cap to see that vent holes are open and baffle is in place

I. Reassemble master cylinder

1. Lubricate master-cylinder bore and all internal rubber parts with clean brake fluid

2. Install rubber washer against shoulder inside master-cylinder bore
3. Install check valve on large end of spring
4. Install check-valve assembly into bore
5. Install spring
6. Install primary cup over end of spring, with concave side toward spring
7. Install piston into bore
8. Install piston retaining ring while compressing piston and spring
9. Install boot and pushrod if required
10. Bleed air from master cylinder
    a. Fill master-cylinder reservoir with extra-heavy-duty brake fluid
    b. Push piston in
    c. Place finger over outlet holes
    d. Release piston
    e. Repeat this operation until a solid stream of fluid flows from outlet

J. Place master cylinder in position; tighten bolts

K. Install hydraulic brake line and tighten

(NOTE: Use care to avoid cross threading.)

L. Install master-cylinder pushrod pin

(NOTE: Check brake pedal free travel; adjust if required.)

M. Fill master cylinder with clean brake fluid

N. Bleed hydraulic system

O. Clean work area; clean and put away all equipment and materials

BRAKE SYSTEMS
UNIT II

JOB SHEET #7 — TEST THE HYDRAULIC SYSTEM

I. Equipment

A. Extra-heavy-duty brake fluid

B. Person to assist you

II. Procedure

(NOTE: Hydraulic brake systems do not cause pulling, grabbing, vibrations, pulsating pedal, squeaks, squeals, clunks, or in most cases, dragging brakes.)

A. Check fluid level in master-cylinder reservoir and fill to within ¼ inch of top of reservoir

B. Start engine

(NOTE: This step is necessary only on power brake models.)

C. Apply brakes and hold a firm pressure for approximately two minutes; check for the following conditions

1. Spongy pedal — With aid of an assistant, test for air entrapment in the hydraulic system

(NOTE: A spongy pedal usually indicates that air is trapped in the hydraulic system or that shoes are not properly fitted to brake drum.)

a. Loosen cap on master cylinder

b. Pump brake pedal rapidly approximately ten times

c. Hold pedal in applied position while assistant removes master-cylinder cap

d. Release pedal quickly and watch for a geyser of fluid from reservoir

(NOTE: If the fluid does form a geyser, bleed the hydraulic system.)

2. Brake warning light

(NOTE: The warning light indicates uneven hydraulic pressure between the front and rear brake systems. Uneven pressure is usually caused by an external brake-fluid leak.)

a. Check for fluid leaks at master cylinder

b. Check for fluid leaks on hydraulic lines and hoses

c. Check wheel cylinders for fluid leaks

d. Repair leaks as necessary

3. Excessive pedal travel

(NOTE: Excessive pedal travel is usually the result of shoes out of adjustment, an excessively worn shoe lining, or low fluid level in reservoir.)

a. Check fluid level and add fluid if necessary

(NOTE: If the reservoir is completely empty, the system will have to be bled.)

b. Remove front tire and wheel assemblies

c. Inspect caliper shoe linings

d. Remove rear tire and wheel assemblies

e. Remove rear brake drums

f. Inspect shoe linings

g. Replace worn shoes if necessary

h. Reinstall rear drums, tires, and wheels

i. Adjust rear brake shoes

j. Reinstall front tires and wheels

k. Bleed hydraulic system

4. Pedal fadeaway — Replace or overhaul master cylinder

(NOTE: Pedal fadeaway is the result of fluid's leaking past the internal piston seals in the master cylinder.)

D. Recheck brake-pedal action after proper repairs have been made

E. Clean work area; clean and put away all equipment and materials

F. Road test, if the conditions have been corrected, to determine if other problems exist

(NOTE: Instructor must accompany you on road test.)

BRAKE SYSTEMS
UNIT II

JOB SHEET #8 — TEST THE VACUUM POWER BOOSTER

I. Equipment and materials

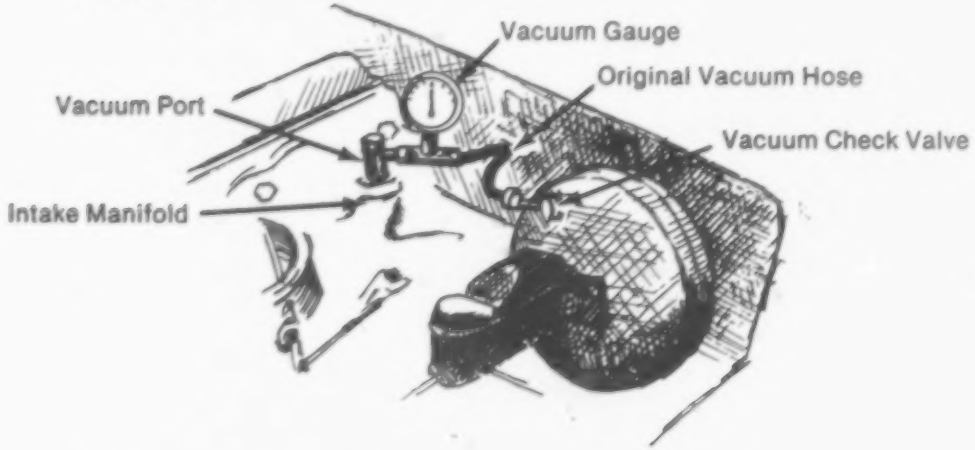
A. Extra-heavy-duty brake fluid

B. Vacuum gauge

II. Procedure

A. Attach vacuum gauge to an intake-manifold vacuum connection (Figure 38)

FIGURE 38



B. Start engine and take vacuum reading at idle speed

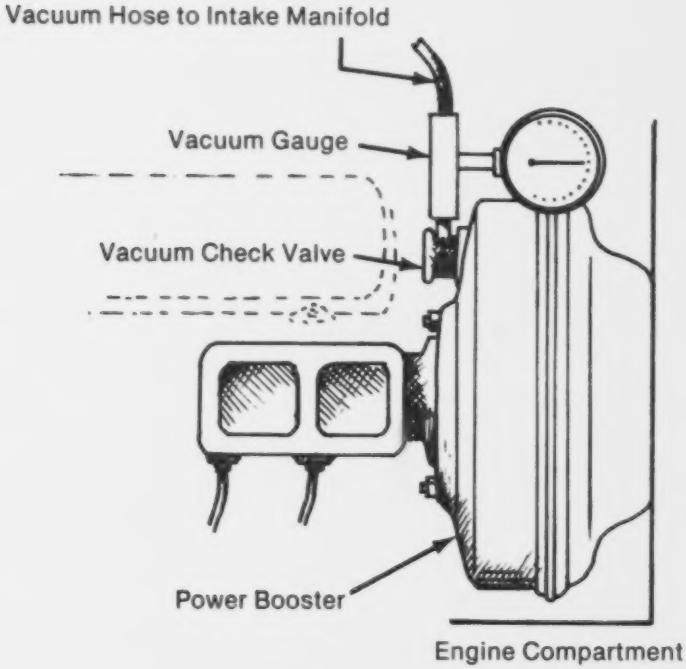
(NOTE: The gauge should read at least 10 inches vacuum. If it reads less than 10 inches, the engine will require repairs to correct this condition.)

C. Turn engine off and remove vacuum gauge from engine connection

JOB SHEET #8

D. Connect gauge to vacuum hose at power-booster check valve (Figure 39)

FIGURE 39



E. Start engine

F. Take a vacuum reading at idle speed

(NOTE: The vacuum reading should be the same as the reading taken at the manifold. If the reading is lower, check for a leak or restriction in the hose.)

G. Turn off engine

H. Remove vacuum gauge

I. Check fluid in master-cylinder reservoir and adjust if necessary

J. Shift transmission into neutral

K. Depress brake pedal several times to exhaust all vacuum in system

L. Hold brake pedal in applied position

JOB SHEET #8

M. Start engine

(NOTE: If the vacuum system is operating, the pedal will tend to fall away under foot pressure and less pressure will be required to hold the pedal in the applied position. Replace the power booster if a reaction is not felt on the pedal.)

N. Check for reserve vacuum leaks

1. Operate engine at fast idle for ten seconds, and then stop engine
2. Let vehicle stand for ten minutes
3. Apply brake pedal with approximately 20 pounds of force

(NOTE: The pedal feel should be the same as that noted when the engine was operating. If the pedal feels hard, replace the vacuum check valve and retest for leaks. If pedal still feels hard, replace the power booster.)

O. Clean work area; clean and put away all equipment and materials

BRAKE SYSTEMS
UNIT II

JOB SHEET #9 — REPAIR A SLIDING-CALIPER DISC BRAKE

I. Equipment and materials

- A. Floor jack
- B. Jack stands
- C. Combination wrench set
- D. Screwdriver set
- E. Wire brush
- F. Brake hone
- G. Brake fluid
- H. C-clamp
- I. Hammer
- J. Drill motor
- K. Appropriate cleaning fluid for brake parts
- L. Bleeding equipment
- M. Shop towels
- N. Metering valve bleeder clip
- O. Bench vise
- P. Appropriate service manual

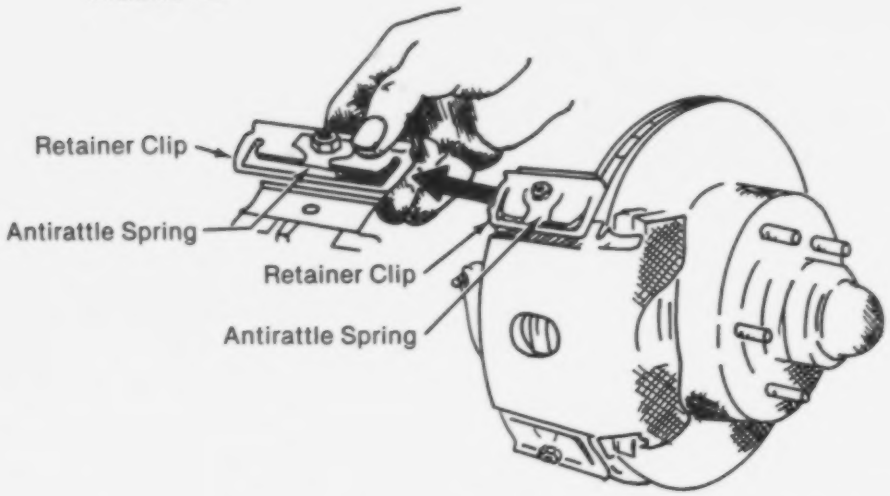
II. Procedure

- A. Raise vehicle and support on jack stands
- B. Remove front wheel covers
- C. Remove wheel and tire assembly

JOB SHEET #9

D. Remove caliper antirattle springs and retainer clips (Figure 40)

FIGURE 40

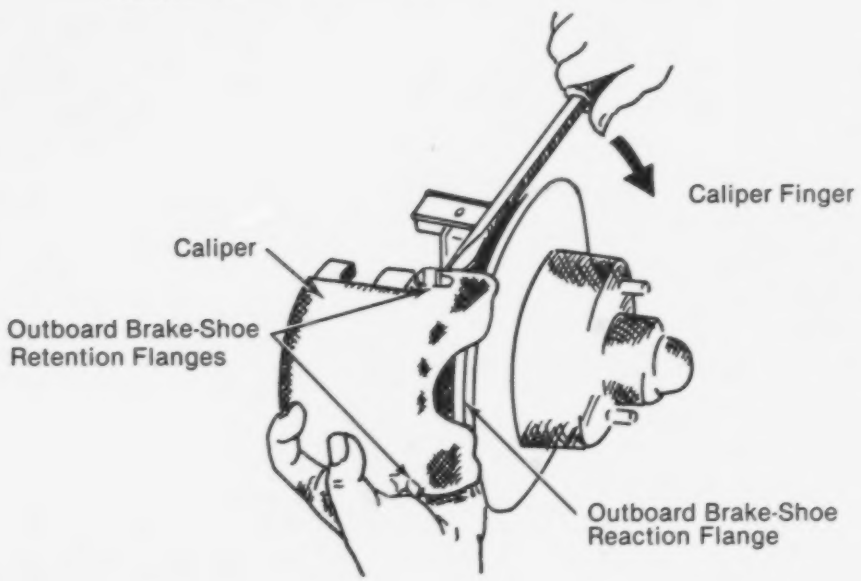


E. Remove caliper assembly from disc by lifting caliper straight out of caliper adapter

(CAUTION: Support the caliper so that the weight is not suspended by the brake hose.)

F. Remove outboard shoe from caliper (Figure 41)

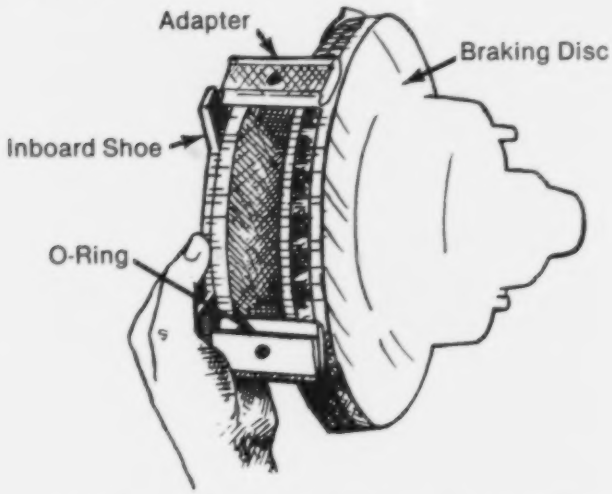
FIGURE 41



JOB SHEET #9

G. Remove inboard shoe from caliper adapter (Figure 42)

FIGURE 42



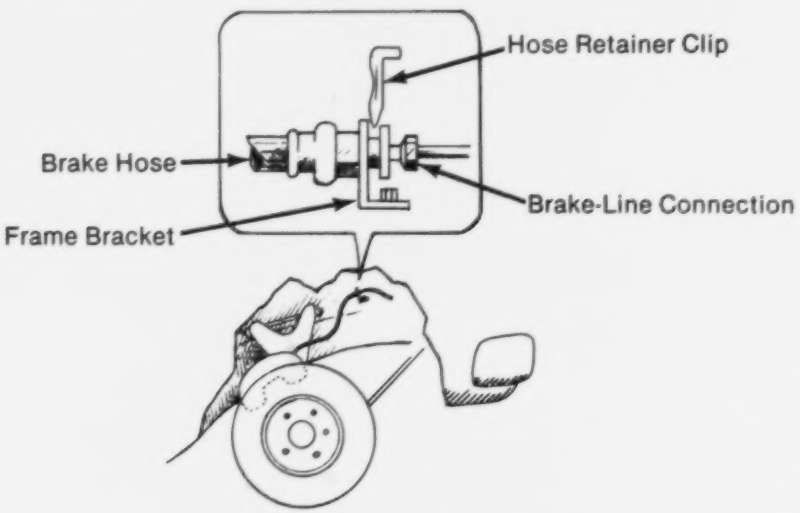
H. Lay caliper assembly on shop towels on upper control arm

I. Pump master cylinder slowly until piston is pushed out of caliper

J. Disconnect brake hose at frame connector (Figure 43)

(NOTE: If caliper pistons from both sides are to be removed, plug the line at the frame connector and remove the other piston.)

FIGURE 43



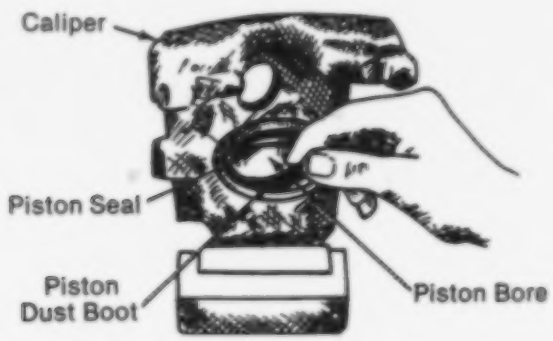
JOB SHEET #9

K. Clamp caliper in vise with protected jaws

(CAUTION: Excessive vise pressure can damage caliper and cylinder.)

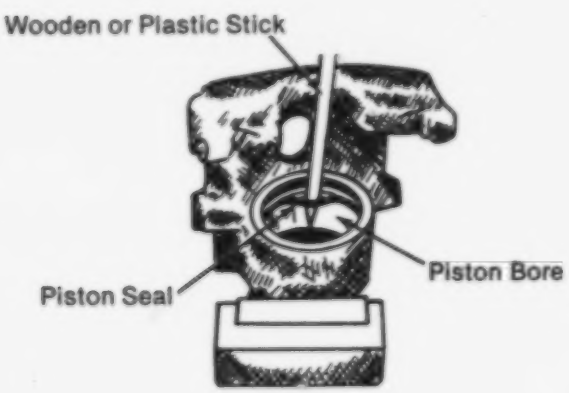
L. Remove piston dust boot (Figure 44)

FIGURE 44



M. Remove piston seal (Figure 45)

FIGURE 45

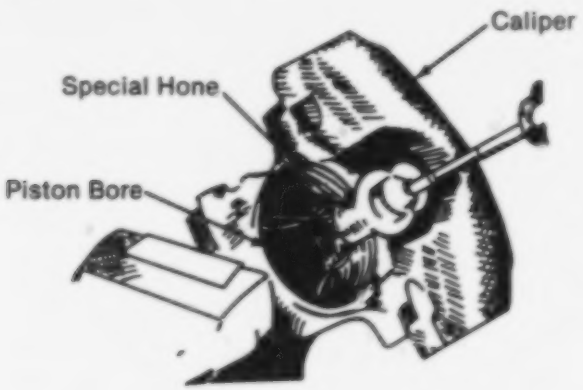


JOB SHEET #9

N. Hone cylinder to remove any scratches or corrosion

(CAUTION: Do not increase the diameter of the cylinder more than 0.002 inch. If the cylinder will not clean up within this specification, the caliper will have to be replaced. See Figure 46.)

FIGURE 46



O. Remove caliper from vise and clean caliper very carefully by flushing cylinder with clean brake fluid to remove all dirt and grit

P. Clean piston with alcohol or a suitable cleaner

Q. Inspect piston for scratches or corrosion

(NOTE: The piston will have to be replaced if it has pits or scratches.)

R. Clamp caliper in vise with protected jaws

(CAUTION: Excessive vise pressure will cause bore distortion and binding of piston.)

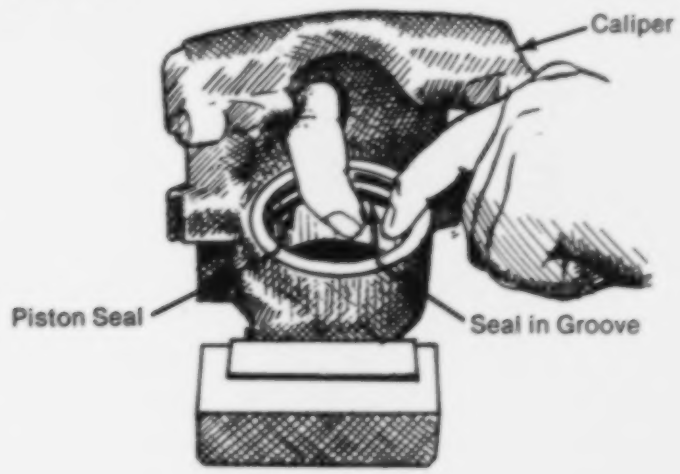
S. Lubricate new caliper piston seal with brake fluid

(NOTE: Some manufacturers provide a special lubricant with the new seals; use this instead of brake fluid.)

JOB SHEET #9

T. Install seal into caliper cylinder groove, making sure not to allow a twist in the seal (Figure 47)

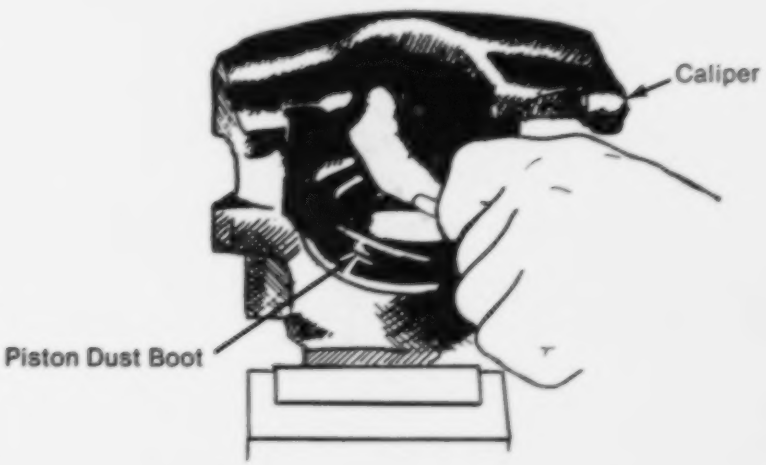
FIGURE 47



U. Lubricate piston dust boot

V. Install dust boot into groove (Figure 48)

FIGURE 48



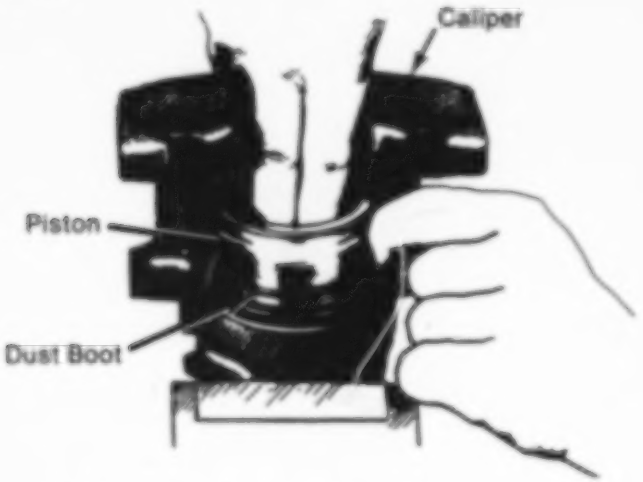
W. Plug pressure inlet hole and close bleeder

JOB SHEET #9

X. Coat piston with brake fluid and start piston into dust boot (Figure 49)

(NOTE: Air entrapped below piston will force boot around piston.)

FIGURE 49



Y. Align and start piston into piston seal

Z. Remove plug from inlet port

AA. Push piston down the bore carefully until bottomed

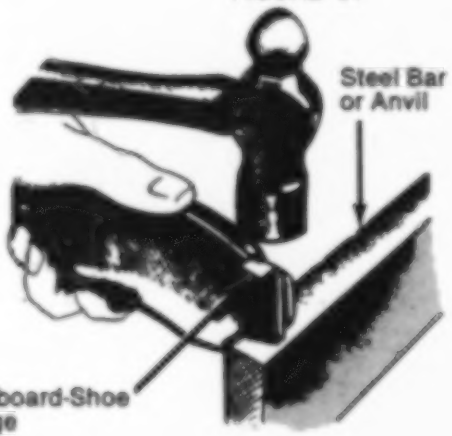
(CAUTION: Apply uniform force to avoid rocking the piston.)

BB. Remove caliper from vise and install outboard shoe into caliper with a slight interference fit

(CAUTION: No clearance should exist between caliper and shoe flanges. Bend flanges to eliminate any vertical movement. See Figures 50 and 51.)

FIGURE 50

FIGURE 51

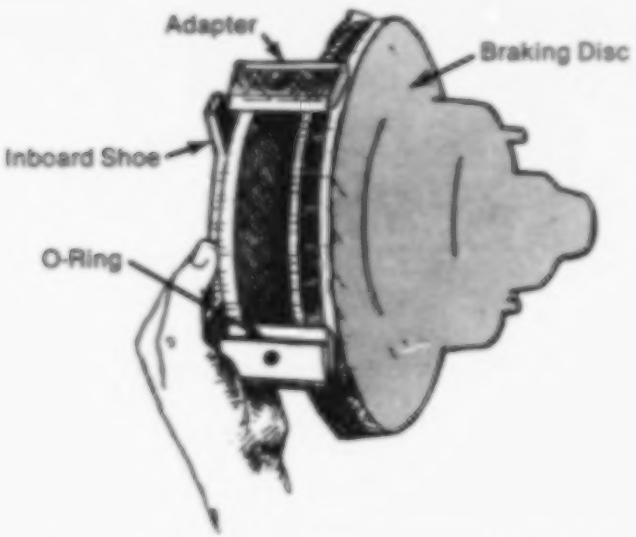


CC. Remove O-rings from caliper adapter and clean adapter ways with a wire brush (See Figure 52.)

DD. Replace O-rings on caliper adapter

EE. Position inboard shoe in caliper adapter

FIGURE 52



FF. Slide caliper assembly slowly into position in adapter over disc

(CAUTION: Avoid damage to caliper piston dust cover as it passes over the inboard shoe.)

GG. Install antirattle springs and retaining clips; torque retaining screws according to specifications

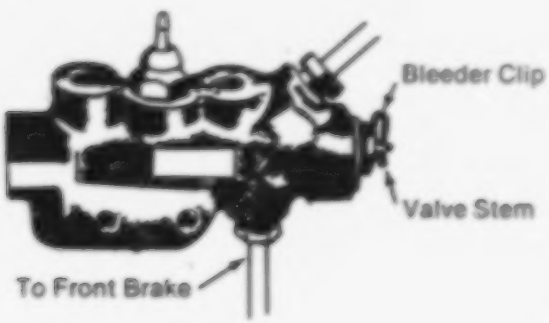
HH. Connect brake hose at frame

JOB SHEET #9

II. Bleed air from system

(NOTE: Systems with metering valves require installation of a bleeder clip on the valve stem when using a pressure bleeder. See Figure 53.)

FIGURE 53



JJ. Reinstall wheel and tire assembly

KK. Reinstall wheel cover

LL. Lower vehicle to floor

MM. Clean work area; clean and put away all equipment and materials

NN. Road test vehicle to check for proper operation

(NOTE: Instructor must accompany you on road test.)

BRAKE SYSTEMS
UNIT II

JOB SHEET #10 — CHECK DISC RUNOUT AND THICKNESS

I. Equipment and materials

- A. Floor jack
- B. Jack stands
- C. Dust-cover remover tool
- D. Combination wrench set
- E. Screwdriver set
- F. Pinch bar
- G. Dial indicator with attachments
- H. 0- to 1-inch and 1- to 2-inch micrometers
- I. Diagonal cutting pliers
- J. Torque wrench
- K. Socket to fit spindle nut
- L. Cotter pin
- M. Straightedge
- N. Feeler gauge
- O. Chalk
- P. Appropriate service manual

II. Procedure

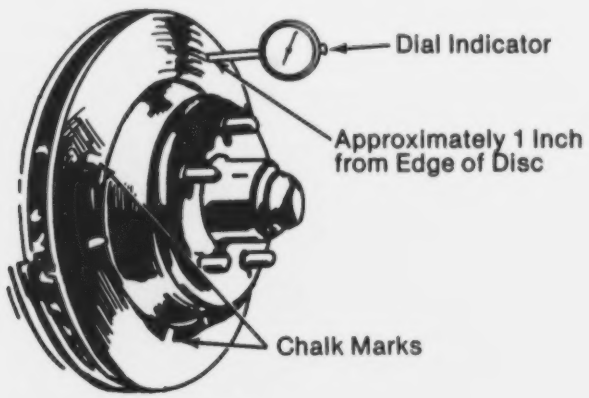
- A. Raise vehicle and support on jack stands
- B. Remove wheel cover
- C. Remove wheel and tire assembly
- D. Remove hub dust cover
- E. Remove cotter pin
- F. Adjust wheel bearing to zero clearance

JOB SHEET #10

G. Attach dial indicator to some portion of suspension so that indicator point will ride on disc approximately 1 inch from outer edge (See Figure 54)

H. Mark disc with chalk every 30 degrees of rotation (Figure 54)

FIGURE 54



I. Set dial indicator to zero

J. Rotate disc and check runout

(NOTE: Total runout should not exceed 0.005 inch in 360 degrees and should not have more than 0.001-inch variation in a 30-degree rotation. Recondition or replace disc if it is not within these limits.)

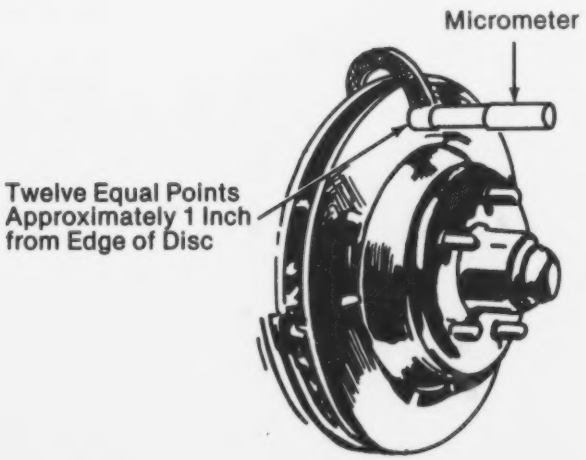
K. Remove disc and hub assembly from spindle

JOB SHEET #10

L. Measure disc approximately 1 inch from outer edge with appropriate-sized micrometer (Figure 55)

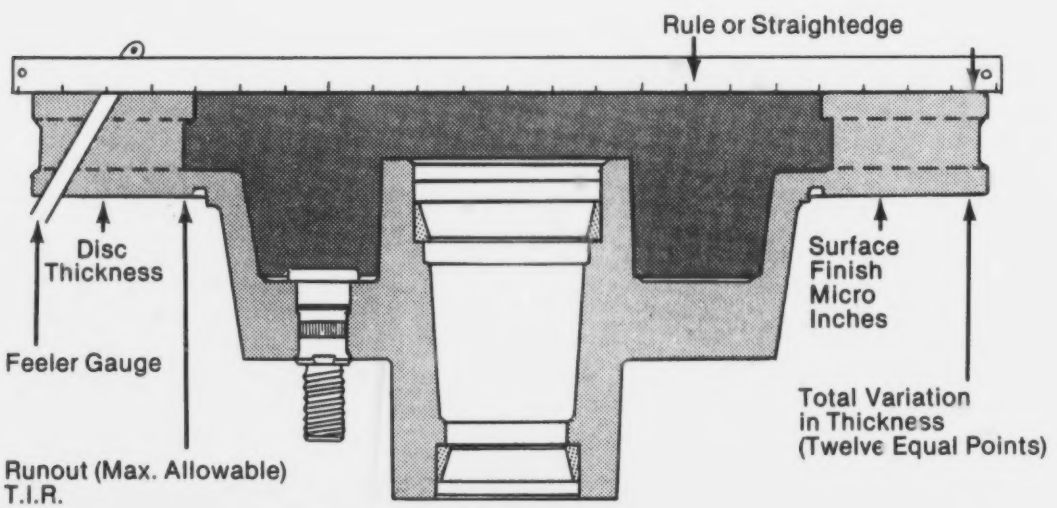
(NOTE: Measure at least four places, equally spaced around the disc. Thickness variation must not exceed 0.0005 inch. If the thickness varies over 0.0005 inch, recondition or replace the disc.)

FIGURE 55



M. Check disc for flatness with a straightedge and feeler gauge across disc diameter (Figure 56)

FIGURE 56



JOB SHEET #10

N. Check disc for heavy scoring, rust pitting, or wear; resurface or replace as necessary

(NOTE: Light scoring or wear is acceptable and will not affect the brake operation.)

O. Check for cracks in disc or hub

(NOTE: If disc or hub has cracks, replace the disc and hub assembly.)

P. Reinstall disc and hub assembly on vehicle and adjust wheel bearings

Q. Reinstall caliper assembly

R. Reinstall tire and wheel assembly

S. Reinstall wheel cover

T. Pump brake pedal several times to position shoes and piston to the disc

U. Lower vehicle to floor

V. Clean work area; clean and put away all equipment and materials

W. Road test vehicle

(NOTE: Instructor must accompany you on the road test.)

BRAKE SYSTEMS
UNIT II

JOB SHEET #11 — ADJUST PARKING BRAKE ON A CRAWLER

I. Equipment — Basic tool set

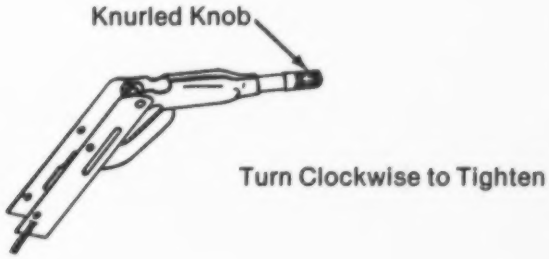
II. Procedure for adjusting brake with brake handle

(NOTE: With parking-brake handle disengaged, barely relieve tension on cable.)

A. Release parking brake

B. Turn knurled knob at end of parking-brake handle clockwise (in) (Figure 57)

FIGURE 57



C. Apply brake

D. Start crawler and try to move it

E. Turn off crawler and repeat procedure as necessary until brake holds

III. Procedure for adjusting brake with clevis fitting

A. Remove floor plate

B. Remove clevis from bracket

C. Turn clevis farther onto end of cable (Figure 58)

FIGURE 58

JOB SHEET #11

D. Replace clevis on bracket

E. Apply brake

F. Start crawler and try to move it

G. Turn off crawler and repeat procedure as necessary until brake holds

(NOTE: If brake cannot be adjusted, replace brake discs or make other repairs as indicated from inspection of brake system.)

H. Clean work area; clean and put away equipment

BRAKE SYSTEMS
UNIT II

TEST

NAME _____ SCORE _____

1. Match terms associated with brake systems to their correct definitions. Write the correct numbers in the blanks. Terms and definitions continue on the following page.

_____a.	Special fluid used in hydraulic brake systems	1. Bleeding the brakes
_____b.	Removal of air from hydraulic brake system	2. Disc brakes
_____c.	High-pressure line used to carry brake fluid from master cylinder to wheel cylinders	3. Inboard shoe
_____d.	Part of brake assembly to which brake lining is attached	4. Wheel cylinder
_____e.	Brake system utilizing a caliper, which compresses brake shoes against a circular disc	5. Brake shoe
_____f.	Resistance to relative movement between two bodies in contact	6. Hydraulic cylinder
_____g.	Pressure lower than atmospheric pressure developed in engine intake manifold and cylinders by movement of cylinder pistons	7. Brake fluid
_____h.	Shoe next to the single piston in caliper on vehicle frame side of brake disc	8. Brake drum
_____i.	Operated by the movement and force of fluid	9. Friction
_____j.	Cylinder that produces, or is controlled by, the motion of fluid	10. Hydraulic
_____k.	Hydraulic cylinder used to force brake fluid to individual wheel cylinders when brakes are applied	11. Master cylinder
_____l.	Hydraulic cylinder actuated by hydraulic pressure; forces brake lining into contact with brake drum	12. Manifold vacuum
_____m.	Cast-iron or aluminum housing that rotates around brake assembly; provides a smooth surface for brake shoes to contact and exert braking action	13. Brake line

TEST

_____n. Device consisting of two plates that are lined with a frictional material and press against sides of a rotating wheel or disc

_____o. Vacuum or hydraulic unit designed to assist operator when applying brakes

_____p. Shoe opposite caliper piston and outside brake disc

_____q. Department of Transportation; federal agency that sets standards for safety items on motor vehicles

14. Power booster
15. Outboard shoe
16. DOT
17. Caliper

2. Describe the purposes of brakes.

_____

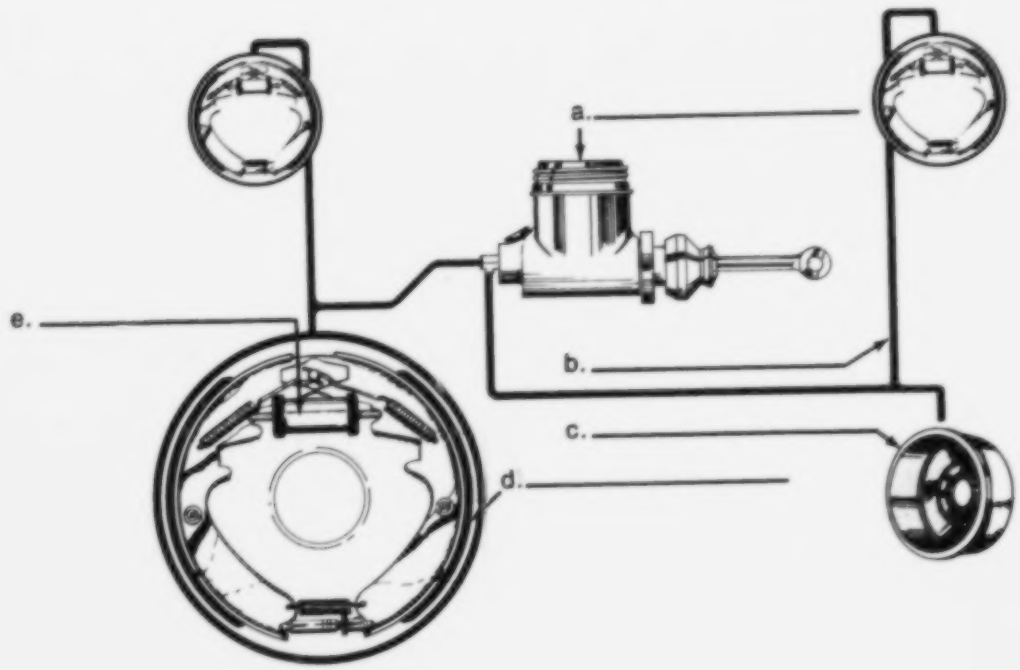
_____

_____

TEST

3. Identify components of a standard brake system. Write the correct names in the blanks.

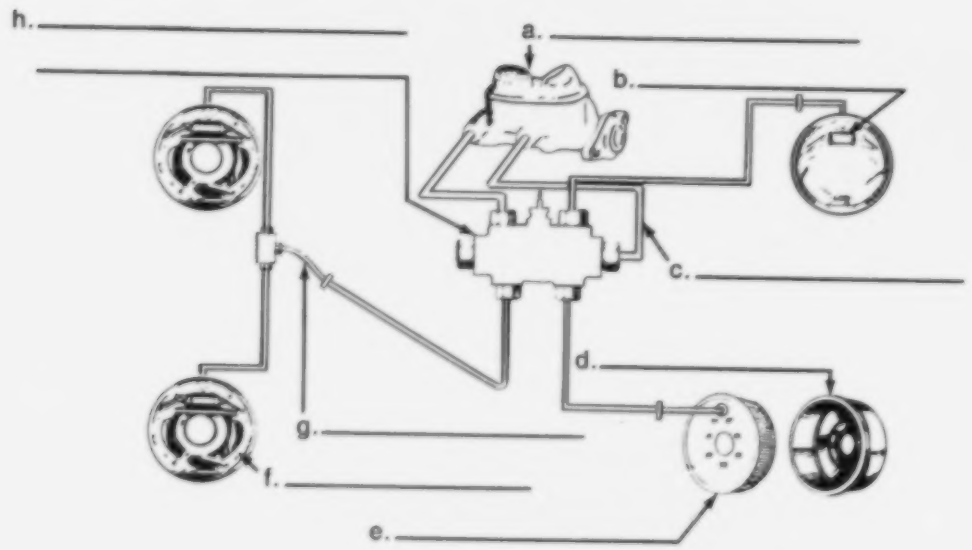
Master cylinder **Brake line** **Wheel cylinder**
Brake shoe **Brake drum**



TEST

4. Identify components of a tandem or dual brake system. Write the correct names in the blanks.

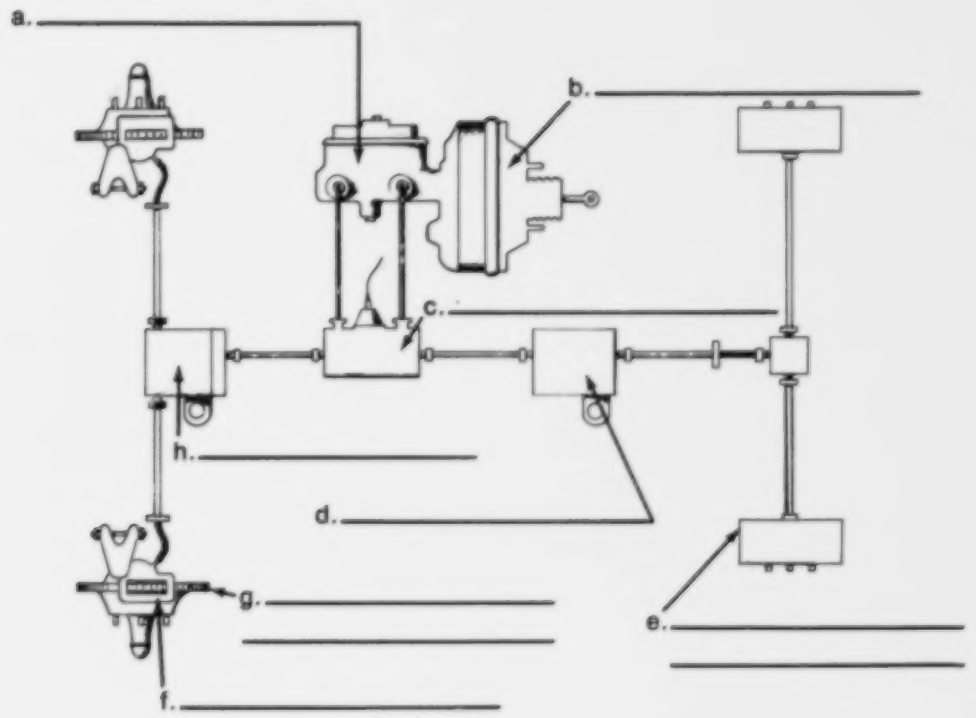
Pressure-differential valve and brake-warning light switch	**Tandem or dual master cylinder**	**Brake line**
Backing plate	**Brake drum**	**Brake flex hose**
	Wheel cylinder	**Brake shoe**



TEST

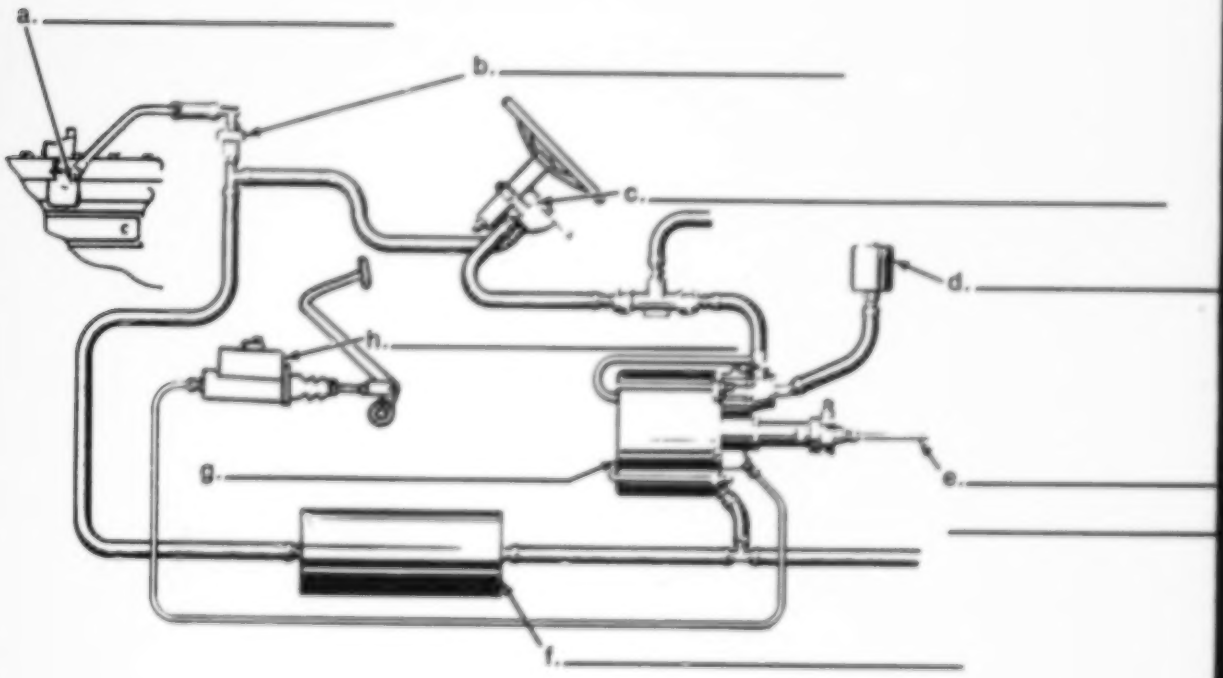
5. Identify major components of a disc brake system. Write the correct names in the blanks.

Master cylinder	**Pressure-differential valve**	**Proportioning valve**
Metering valve	**Front disc or rotor assembly**	**Caliper assembly**
Power booster	**Rear drum or disc brake assembly**	



6. Identify components of a vacuum brake system. Write the correct names in the blanks.

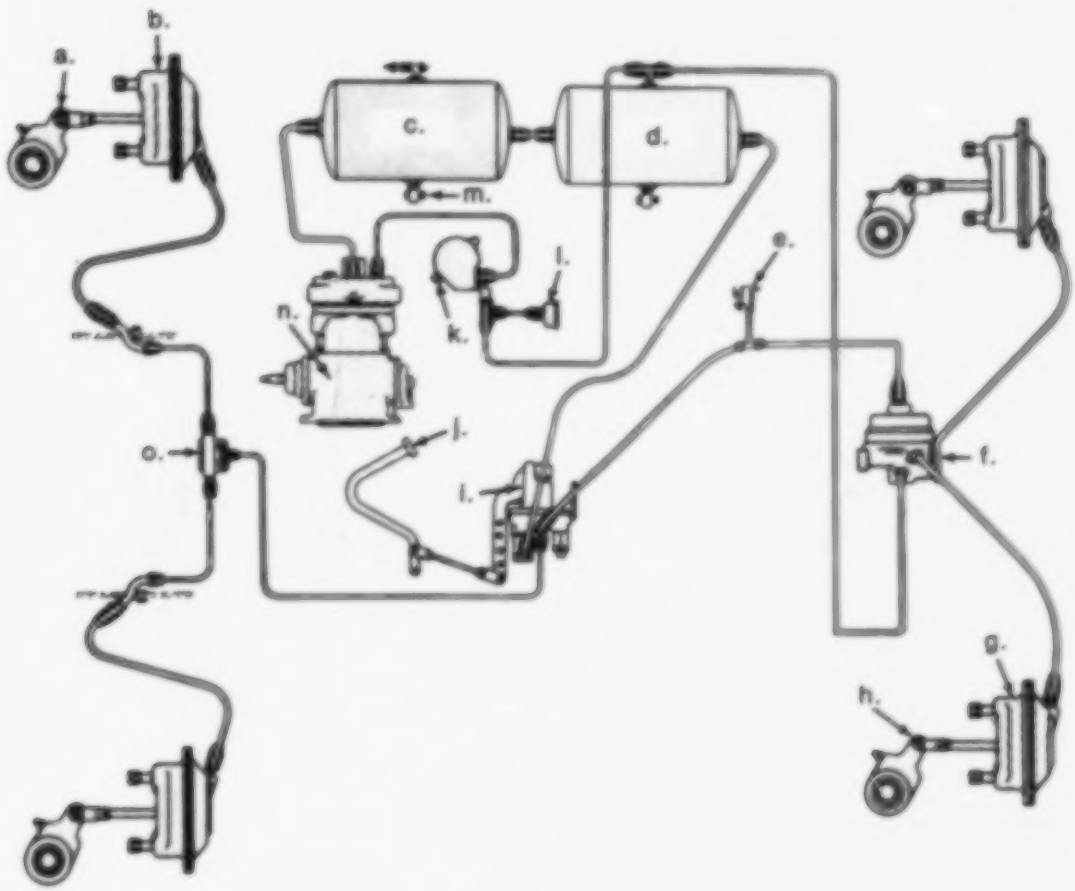
Intake manifold	**Hand control valve to trailer**	**Hydraulic line to wheel cylinder**
Check valve	**Master cylinder**	**Hydrovac**
Air cleaner	**Reserve tank**	



TEST

7. Identify components of an air brake system. Write the correct names in the blanks on the following page.

Front brake chamber	**Governor**	**Stoplight switch**
Quick-release valve	**Brake valve**	**Rear slack adjuster**
Brake pedal	**Drain cock**	**Reservoir #1**
Rear brake chamber	**Front slack adjuster**	**Reservoir #2**
Compressor	**Air gauge**	**Relay valve**



TEST

a. _____

b. _____

c. _____

d. _____

e. _____

f. _____

g. _____

h. _____

i. _____

j. _____

k. _____

l. _____

m. _____

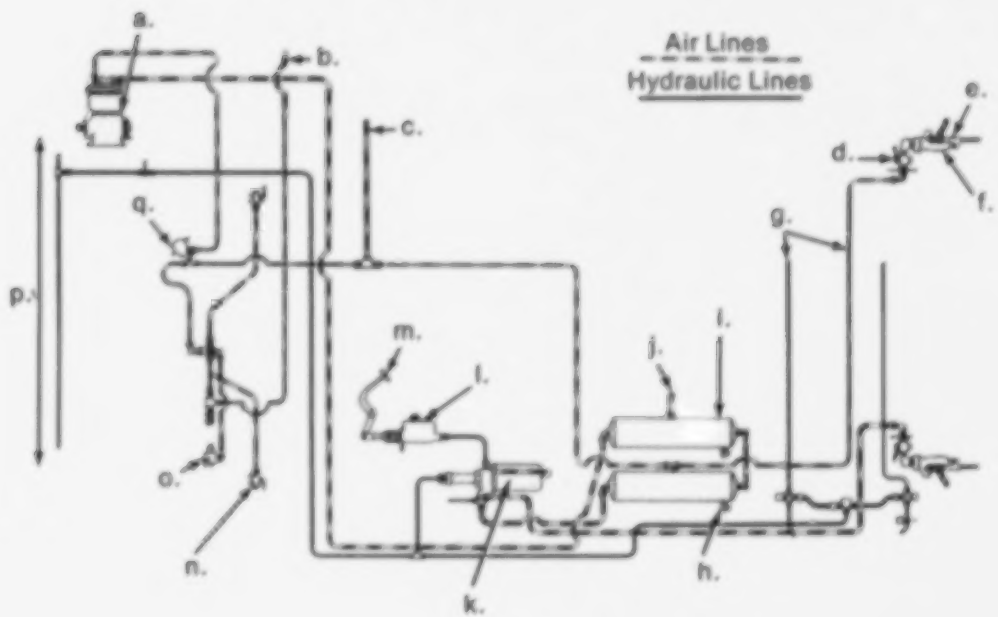
n. _____

o. _____

TEST

8. Identify components of an air-over-hydraulic brake system. Write the correct names in the blanks on the following page.

Compressor	**Air-supply valve**	**Lines to rear wheel brakes**
Governor	**Air/hydraulic cylinder**	**Brake pedal**
Safety valve	**Lines to front wheel brakes**	**Master cylinder**
Reservoir	**Dummy coupling**	**Hose coupling**
Drain valve	**Air line to windshield wipers**	**Cutout cock**
Low-pressure indicator	**Air line to horn**	



TEST

a. _____

b. _____

c. _____

d. _____

e. _____

f. _____

g. _____

h. _____

i. _____

j. _____

k. _____

l. _____

m. _____

n. _____

o. _____

p. _____

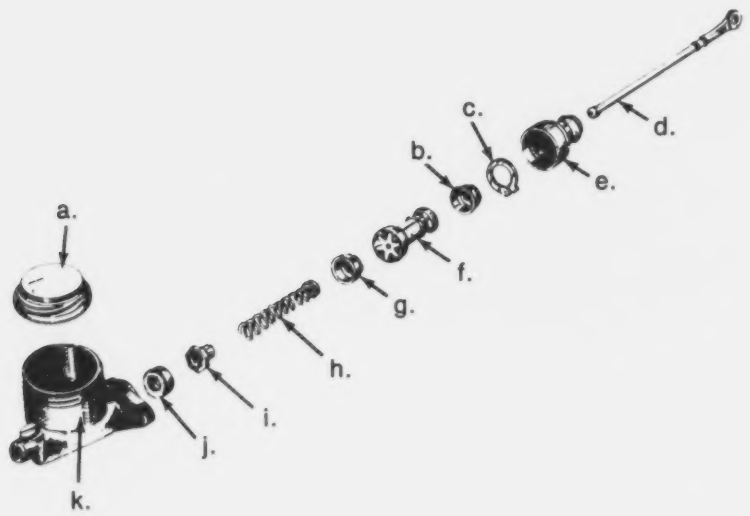
q. _____

1368

TEST

9. Identify parts of a standard master cylinder. Write the correct names in the blanks.

Fluid reservoir	**Piston lock ring**	**Piston**
Filler cap	**Piston return spring**	**Residual-pressure check-valve assembly**
Primary cup	**Pushrod**	**Rubber valve-seat washer**
Secondary cup	**Boot**	



a. _____

b. _____

c. _____

d. _____

e. _____

f. _____

g. _____

h. _____

i. _____

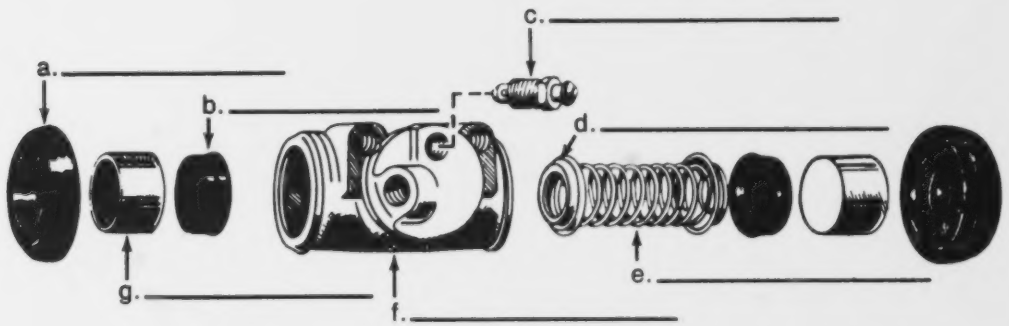
j. _____

k. _____

TEST

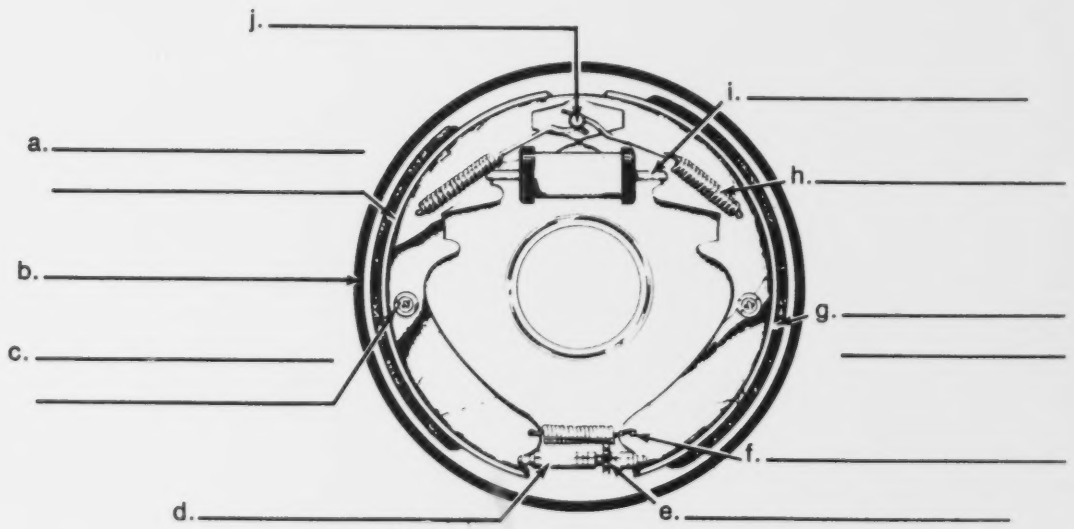
10. Identify parts of a wheel cylinder. Write the correct names in the blanks.

Boot
Spring
Piston
Cup
Bleeder screw
Cup expander
Cylinder



11. Identify parts of a standard brake assembly. Write the correct names in the blanks.

Primary brake shoe and lining
Secondary brake shoe and lining
Adjusting-screw spring
Return spring
Backing plate
Anchor pin
Star wheel
Brake-shoe retainer
Adjusting screw
Connecting link



TEST

12. List types of disc brake calipers.

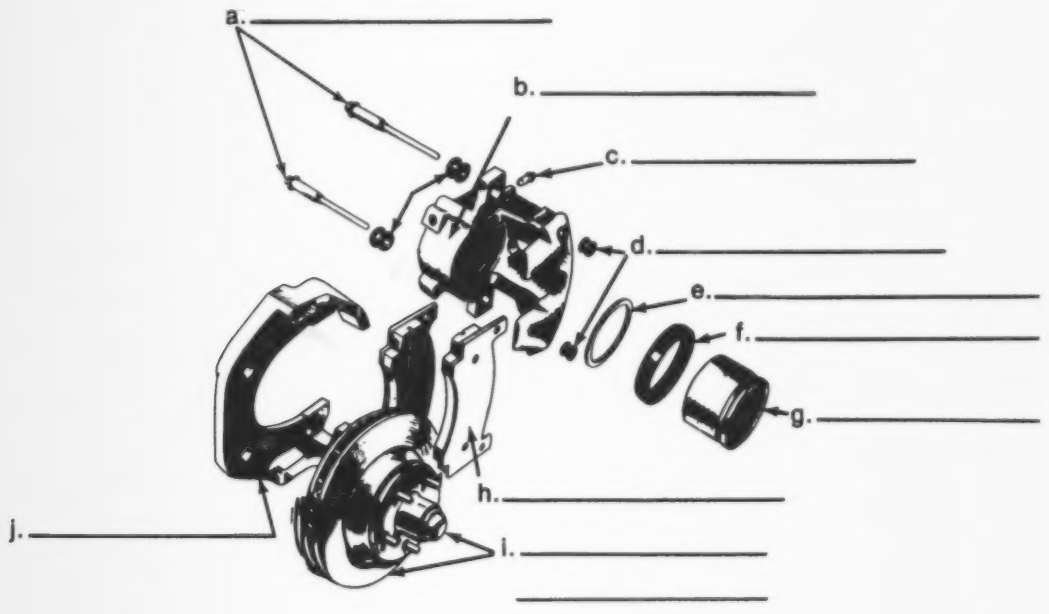
a. _____

b. _____

c. _____

13. Identify parts of a floating-caliper disc brake. Write the correct names in the blanks.

Disc and hub assembly	**Bleeder screw**	**Caliper**
Mounting bolts	**Boot**	**Seal**
Bushings	**Caliper adapter**	
Shoe and lining	**Piston**	



TEST

14. Discuss reasons disc brakes may require power boosters.

_____

_____

15. Name types of energy for power boosters.

a. _____

b. _____

16. Describe brake operation.

a. Brake pedal depressed — _____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

b. Brake pedal released — _____

_____

_____

_____

17. List five factors that may cause difficulties in brake adjustment.

a. _____

b. _____

TEST

c. _____

d. _____

e. _____

18. Name types of brake linings.

a. _____

b. _____

19. List three requirements of extra-heavy-duty brake fluid.

a. _____

b. _____

c. _____

(NOTE: Test question 20 lists the job sheets. They are an important part of this test. If they have not been completed, check with your instructor.)

20. Demonstrate the ability to

a. Adjust brake shoes.

b. Bleed the brake system.

c. Remove, inspect, and reinstall brake drums.

d. Remove and replace brake shoes.

e. Remove, recondition, and reinstall a wheel cylinder.

f. Remove, recondition, and reinstall a master cylinder on a crawler.

g. Test the hydraulic system.

h. Test the vacuum power booster.

i. Repair a sliding-caliper disc brake.

j. Check disc runout and thickness.

k. Adjust parking brake on a crawler.

BRAKE SYSTEMS
UNIT II

ANSWERS TO TEST

1.	a.	7	g.	12	m.	8
	b.	1	h.	3	n.	17
	c.	13	i.	10	o.	14
	d.	5	j.	6	p.	15
	e.	2	k.	11	q.	16
	f.	9	l.	4		

2. Description should include the following — Slowing, stopping, holding, and in some cases, steering an object

3.	a.	Master cylinder	d.	Brake shoe
	b.	Brake line	e.	Wheel cylinder
	c.	Brake drum		

4.	a.	Tandem or dual master cylinder	e.	Backing plate
	b.	Wheel cylinder	f.	Brake shoe
	c.	Brake line	g.	Brake flex hose
	d.	Brake drum	h.	Pressure-differential valve and brake-warning light switch

5.	a.	Master cylinder	e.	Rear drum or disc brake assembly
	b.	Power booster	f.	Caliper assembly
	c.	Pressure-differential valve	g.	Front disc or rotor assembly
	d.	Proportioning valve	h.	Metering valve

6.	a.	Intake manifold	e.	Hydraulic line to wheel cylinder
	b.	Check valve	f.	Reserve tank
	c.	Hand control valve to trailer	g.	Hydrovac
	d.	Air cleaner	h.	Master cylinder

ANSWERS TO TEST

7.
a. Front slack adjuster
b. Front brake chamber
c. Reservoir #1
d. Reservoir #2
e. Stoplight switch
f. Relay valve
g. Rear brake chamber
h. Rear slack adjuster
i. Brake valve
j. Brake pedal
k. Governor
l. Air gauge
m. Drain cock
n. Compressor
o. Quick-release valve

8.
a. Compressor
b. Air line to windshield wipers
c. Air line to horn
d. Cutout cock
e. Dummy coupling
f. Hose coupling
g. Lines to rear wheel brakes
h. Drain valve
i. Reservoir
j. Safety valve
k. Air/hydraulic cylinder
l. Master cylinder
m. Brake pedal
n. Air-supply valve
o. Low-pressure indicator
p. Lines to front wheel brakes
q. Governor

9.
a. Filler cap
b. Secondary cup
c. Piston lock ring
d. Pushrod
e. Boot
f. Piston
g. Primary cup
h. Piston return spring
i. Residual-pressure check-valve assembly
j. Rubber valve-seat washer
k. Fluid reservoir

ANSWERS TO TEST

10. a. Boot
    b. Cup
    c. Bleeder screw
    d. Cup expander
    e. Spring
    f. Cylinder
    g. Piston

11. a. Primary brake shoe and lining
    b. Backing plate
    c. Brake-shoe retainer
    d. Adjusting screw
    e. Star wheel
    f. Adjusting-screw spring
    g. Secondary brake shoe and lining
    h. Return spring
    i. Connecting link
    j. Anchor pin

12. a. Fixed
    b. Floating
    c. Sliding

13. a. Mounting bolts
    b. Caliper
    c. Bleeder screw
    d. Bushings
    e. Seal
    f. Boot
    g. Piston
    h. Shoe and lining
    i. Disc and hub assembly
    j. Caliper adapter

14. Discussion should include the following
    a. Disc shoes have no servo action
    b. Disc shoe linings have less contact surface than drum brake shoes

15. a. Vacuum
    b. Hydraulic

ANSWERS TO TEST

16. Description should include the following

    a. Brake pedal depressed

        1) Master cylinder forces brake fluid through check valve into brake lines

        2) Brake fluid travels through brake lines to wheel cylinders

        3) Force of brake fluid by master cylinder causes wheel-cylinder cups and pistons to move outward

        4) Movement caused by wheel-cylinder pistons forces brake shoe and lining to make contact with brake drum

        5) Force of fluid and contact of brake lining with brake drum cause vehicle to slow or stop

    b. Brake pedal released — Return springs pull brake shoes back to stop position, forcing brake fluid to return to master-cylinder reservoir

17. Answer should include any five of the following

    a. Broken disc or shoes

    b. Broken linings

    c. Cracked linings

    d. Uneven linings

    e. Foreign objects between lining and drums

    f. Warped shoes or bands

    g. Bent shoes or bands

    h. Linkage difficulties

18. a. Molded asbestos

    b. Woven

19. Answer should include any three of the following

    a. Must have high boiling point

ANSWERS TO TEST

b. Must have low freezing point

c. Must be of consistent viscosity

d. Must be noncorrosive

e. Must be water tolerant

f. Must possess lubricating ability

20. Performance skills evaluated to the satisfaction of the instructor

POWER TRAINS
UNIT I

UNIT OBJECTIVE

After completing this unit, the student should be able to remove, disassemble, inspect, repair, assemble, and install components of the power train. The student will show this knowledge by completing job sheets and unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match to their correct definitions terms associated with power trains.
2. State the purpose of the power train.
3. List jobs performed by the power train.
4. Match basic parts of the power train to their correct functions.
5. Label basic ways of transmitting power.
6. Describe the principle of the disc clutch.
7. Describe the principle of the transmission.
8. Describe the principle of the differential.
9. Match types of clutches to their correct operations.
10. Select from a list major types of clutch operating mechanisms.
11. Identify components of a clutch assembly.
12. Distinguish between engaged and disengaged clutch operation.
13. Identify methods used to actuate clutch release.
14. Select from a list symptoms that may occur when clutch housing bore has excessive runout.
15. Match clutch malfunctions to probable causes.
16. Describe the purpose of the transmission.
17. Identify major parts of a transmission.

OBJECTIVE SHEET

18. Label major types of mechanical transmissions.
19. Select from a list common types of synchronizers.
20. Identify parts of a typical synchronizer.
21. Discuss operation of a three-speed synchromesh transmission.
22. Describe the hydraulic-assist transmission.
23. Describe how hydraulic clutches and gear trains work together.
24. Name basic types of gear sets used in hydraulic-assist transmissions.
25. Select from a list basic parts of a planetary gear system.
26. Describe jobs that oil performs in a hydraulic-assist transmission.
27. Label basic types of hydraulic transmissions.
28. State factors that control operation of hydrostatic drive.
29. List the advantages of hydrostatic drives.
30. Distinguish between hydrostatic drives and torque converters.
31. Distinguish between a torque converter and a fluid coupling.
32. Describe jobs that oil performs in a hydraulic control system.
33. Identify components of a drive (propeller) shaft.
34. Identify types of U-joints (universal joints).
35. List methods of controlling drive-line vibration.
36. Describe how differential locks are used.
37. Label types of differential locks.
38. Describe final drive.
39. Select from a list major types of final drive systems.
40. Distinguish between live axle and dead axle.
41. List types of rear axle bearings.

OBJECTIVE SHEET

42. Demonstrate the ability to

a. Adjust clutch linkage free travel.

b. Remove a clutch assembly.

c. Inspect a clutch assembly.

d. Check clutch housing alignment.

e. Install a clutch assembly.

f. Remove and reinstall a standard transmission.

g. Disassemble, inspect, and reassemble a three-speed transmission.

h. Perform a road test for transmission diagnosis.

i. Replace an extension housing bushing and seal.

j. Tune up an automatic transmission.

k. Remove and reinstall a drive (propeller) shaft.

l. Remove and reinstall a cross-and-roller U-joint.

m. Remove and reinstall a ball-and-trunnion U-joint.

n. Balance a drive (propeller) shaft.

o. Check and adjust U-joint angles.

p. Measure backlash between ring gear and drive pinion.

q. Test ring gear and drive pinion gear tooth contact pattern.

r. Install a drive pinion seal.

s. Install a ball-bearing-type axle shaft bearing and seal.

t. Adjust drive pinion bearing preload with carrier assembly removed.

u. Adjust backlash and carrier bearing preload.

v. Remove and reinstall a rear axle housing assembly.

w. Disassemble, inspect, reassemble, and adjust an integral carrier rear axle.

POWER TRAINS
UNIT I

SUGGESTED ACTIVITIES

I. Suggested activities

A. Order films and other materials to supplement unit.

(NOTE: Manufacturers and equipment dealers are the best sources for these materials.)

B. Gather equipment and materials for job sheet demonstrations.

C. Obtain transparencies.

(NOTE: Transparencies are available from AGC and CIMC.)

D. Provide students with objective sheet.

E. Discuss unit and specific objectives.

F. Provide students with information and job sheets.

G. Discuss information sheet.

H. Demonstrate and discuss procedures outlined in the job sheets.

I. Because this unit is lengthy and complex, break into smaller sections for ease of teaching and testing.

J. Give test.

K. Complete appropriate section of competency profiles.

(NOTE: Competency profiles are available from AGC and CIMC.)

II. Instructional materials

A. Objective sheet

B. Suggested activities

C. Information sheet

D. Transparency masters

1. TM #1 — Parts of a Power Train

2. TM #2 — Clutch Operation

3. TM #3 — Clutch Controls
4. TM #4 — Transmission Operation (Neutral)
5. TM #5 — Transmission Operation (First Gear)
6. TM #6 — Transmission Operation (Second Gear)
7. TM #7 — Transmission Operation (Third Gear)
8. TM #8 — Transmission Operation (Reverse)
9. TM #9 — Hydraulic Oil Circuit for Typical Hydraulic-Assist Transmission
10. TM #10 — Drive (Propeller) Shaft Components
11. TM #11 — Drive (Propeller) Shaft Components (Continued)
12. TM #12 — Methods of Controlling Drive Line Vibration
13. TM #13 — Tapered Roller Rear Axle Bearing
14. TM #14 — Ball-Type Rear Axle Bearing
15. TM #15 — Flat Roller Rear Axle Bearing

E. Job sheets

1. Job Sheet #1 — Adjust Clutch Linkage Free Travel
2. Job Sheet #2 — Remove a Clutch Assembly
3. Job Sheet #3 — Inspect a Clutch Assembly
4. Job Sheet #4 — Check Clutch Housing Alignment
5. Job Sheet #5 — Install a Clutch Assembly
6. Job Sheet #6 — Remove and Reinstall a Standard Transmission
7. Job Sheet #7 — Disassemble, Inspect, and Reassemble a Three-Speed Transmission
8. Job Sheet #8 — Perform a Road Test for Transmission Diagnosis
9. Job Sheet #9 — Replace an Extension Housing Bushing and Seal
10. Job Sheet #10 — Tune Up an Automatic Transmission

SUGGESTED ACTIVITIES

11. Job Sheet #11 — Remove and Reinstall a Drive (Propeller) Shaft

12. Job Sheet #12 — Remove and Reinstall a Cross-and-Roller U-Joint

13. Job Sheet #13 — Remove and Reinstall a Ball-and-Trunnion U-Joint

14. Job Sheet #14 — Balance a Drive (Propeller) Shaft

15. Job Sheet #15 — Check and Adjust U-Joint Angles

16. Job Sheet #16 — Measure Backlash Between Ring Gear and Drive Pinion

17. Job Sheet #17 — Test Ring Gear and Drive Pinion Gear Tooth Contact Pattern

18. Job Sheet #18 — Install a Drive Pinion Seal

19. Job Sheet #19 — Install a Ball-Bearing-Type Axle Shaft Bearing and Seal

20. Job Sheet #20 — Adjust Drive Pinion Bearing Preload with Carrier Assembly Removed

21. Job Sheet #21 — Adjust Backlash and Carrier Bearing Preload

22. Job Sheet #22 — Remove and Reinstall a Rear Axle Housing Assembly

23. Job Sheet #23 — Disassemble, Inspect, Reassemble, and Adjust an Integral Carrier Rear Axle

F. Test

G. Answers to test

III. Unit references

A. Armstrong, Ivan J. *Auto Mechanics: Volume II.* Stillwater, Oklahoma: State Department of Vocational and Technical Education/Curriculum and Instructional Materials Center, 1978.

B. Deere and Company. *Fundamentals of Service: Power Trains,* 2nd ed. Moline, Illinois: John Deere Service Publications, Dept. F, 1972.

C. Hendrix, Laborn J. "Bud." *Heavy Equipment Operator Instructional Materials: Basic Core, Volume I.* Stillwater, Oklahoma: State Department of Vocational and Technical Education/ Curriculum and Instructional Materials Center, and The Associated General Contractors of America, 1981.

POWER TRAINS
UNIT I

INFORMATION SHEET

I. Terms and definitions

A. Backlash — Distance that one gear can be moved back and forth without moving the gear into which it is meshed

B. Cluster gear — Group of gears made on a common casting; used in a standard transmission to connect main drive gear to first, second, and reverse idler gears

C. Clutch disc — Plate that provides friction between pressure plate and flywheel

D. Clutch disc spin — Time it takes for clutch disc to stop spinning after clutch release

E. Constant mesh — Gears that are always in mesh with each other

F. Countergear — Gear that rotates backward

(NOTE: The countergear is the cluster gear in a standard transmission.)

G. Differential — Unit that drives both rear wheels at the same time but allows them to turn at different speeds when negotiating turns

H. Drive line — Driving connection made of one or more propeller shafts between transmission and differential

I. Flywheel — Heavy metal disc that has a friction surface for clutch plate and supports all clutch components

J. Free travel — Amount of clutch pedal or lever movement before release bearing contacts pressure plate fingers

K. Full-floating axle — Axle that drives the wheel; wheel is supported and retained by a hub containing two roller bearings that are attached to axle housing

(NOTE: The inner ends of all types of axles are supported by the differential.)

L. Gear ratio — Number of turns made by a driving gear in relation to one full turn of the driven gear

M. Gear tooth clearance — Distance separating two gear teeth that are meshed together

INFORMATION SHEET

N. Idler gear — Gear in transmission used to change direction of rotation of output shaft

O. Nonslip differential — Special traction differential that automatically transfers torque to the wheel that is not slipping when loss of drive force occurs in other wheel

(NOTE: Rear axle service in the nonslip differential is similar to that in the conventional units, with the exception of the clutch units.)

P. Pilot bearing — Bearing located in flywheel flange of crankshaft; allows for correct support and alignment of transmission input shaft

Q. Preload — Adjustment of antifriction bearings so that they are under mild pressure; tested by amount of torque in inch pounds required to turn shaft

R. Pressure plate — Housing, spring, and plate assembly that provides pressure to clamp clutch disc between pressure plate and flywheel

S. Propeller shaft — Shaft that connects transmission to rear axle through differential to propel vehicle

T. Release bearing — Bearing that provides a method of releasing pressure plate spring pressure

U. Release fork — Y-shaped lever inside clutch housing used to engage and disengage clutch

V. Semifloating axle — Axle that supports, retains, and drives the wheel; outer end of axle is supported by a bearing in the axle housing

W. Slip joint — Variable length connection at one end of a propeller shaft that allows shaft to vary in length as vehicle body moves up and down in relation to rear axle

X. Synchronizer — Device in transmission that causes two gears being shifted together to rotate at the same speed

Y. Synchromesh transmission — Transmission using synchronizers that prevent grinding of gear teeth when gears are shifted

Z. Three-quarter floating axle — Axle that retains and drives the wheel; load is supported by means of a hub and bearing assembly on the axle housing

AA. Torque — Turning or twisting effort

BB. U-joint (universal joint) — Coupling that allows power to be transferred through an angle

INFORMATION SHEET

CC. U-joint timing — Procedure of aligning the yokes of a two- (or more) piece propeller shaft to help control whirl and vibration in propeller shaft

DD. Whirl — Propeller shaft runout or unbalanced condition; causes shaft to act similarly to the loop action of a rope held at both ends and swung in an arc

II. Purpose of the power train — To transfer power from power source to the wheels or tracks (Figures 1 and 2)

EXAMPLE: Power train for four-wheel-drive machine

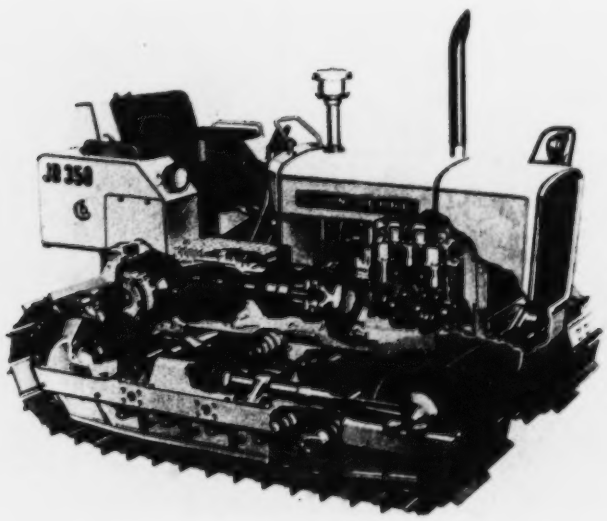
FIGURE 1

Courtesy of Deere and Company, Moline, Illinois.

INFORMATION SHEET

EXAMPLE: Power train on a crawler tractor

FIGURE 2



Courtesy of Deere and Company, Moline, Illinois.

III. Jobs performed by the power train

A. Connecting and disconnecting power

B. Selecting speed ratios

C. Providing a means of reversing

D. Equalizing power to drive wheels or tracks for turning

IV. Functions of basic parts of the power train (Transparency #1)

A. Engine — Provides power

B. Transmission — Selects speed and direction

C. Drive shaft — Connects transmission to differential

D. Differential — Equalizes power for turning

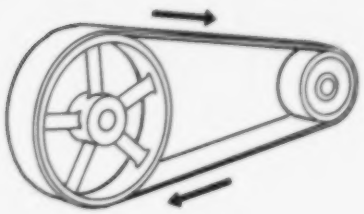
E. Final drive — Gives final reduction in speed and increase in torque to drive wheels

INFORMATION SHEET

V. Basic ways of transmitting power (Figures 3-5)

A. Friction

FIGURE 3



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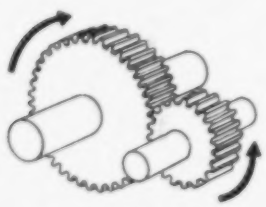
B. Gears

FIGURE 4



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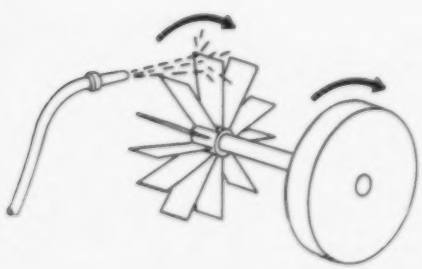
C. Fluid

FIGURE 5



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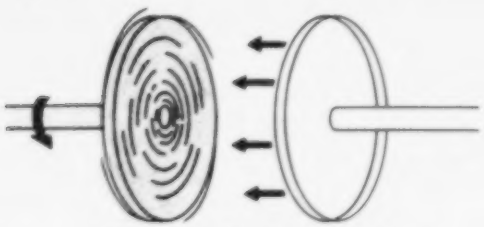
INFORMATION SHEET

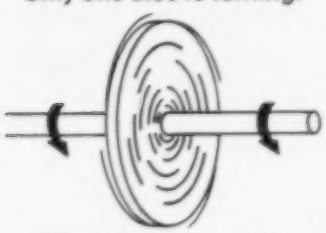
VI. Principle of the disc clutch — Think of the disc clutch as two discs, each on a separate shaft; when discs are not touching, one can spin very fast without affecting the other; but, if they are moved together while one is spinning, the other will also turn, and instantly both shafts will turn as one unit (Figure 6)

EXAMPLE:

FIGURE 6



Only one disc is turning.



Both discs are turning.

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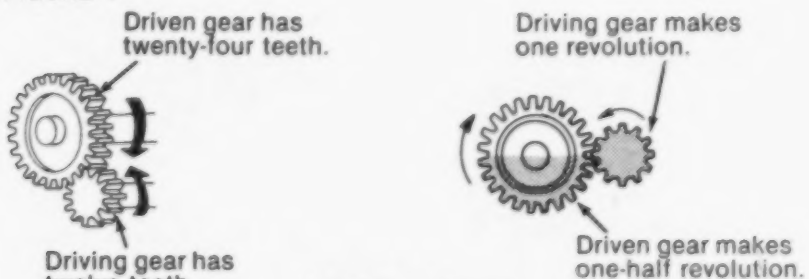
VII. Principle of the transmission — A system of gears allows the speed of the drive wheels to change in relation to the engine (Figure 7)

(NOTE: The transmission allows slow speeds for starting and faster speeds to match various loads and conditions.)

EXAMPLE:

FIGURE 7


Driven gear has twenty-four teeth.
Driving gear makes one revolution.
Driving gear has twelve teeth.
Driven gear makes one-half revolution.
Small gear always turns faster.

How the Transmission Selects a Speed

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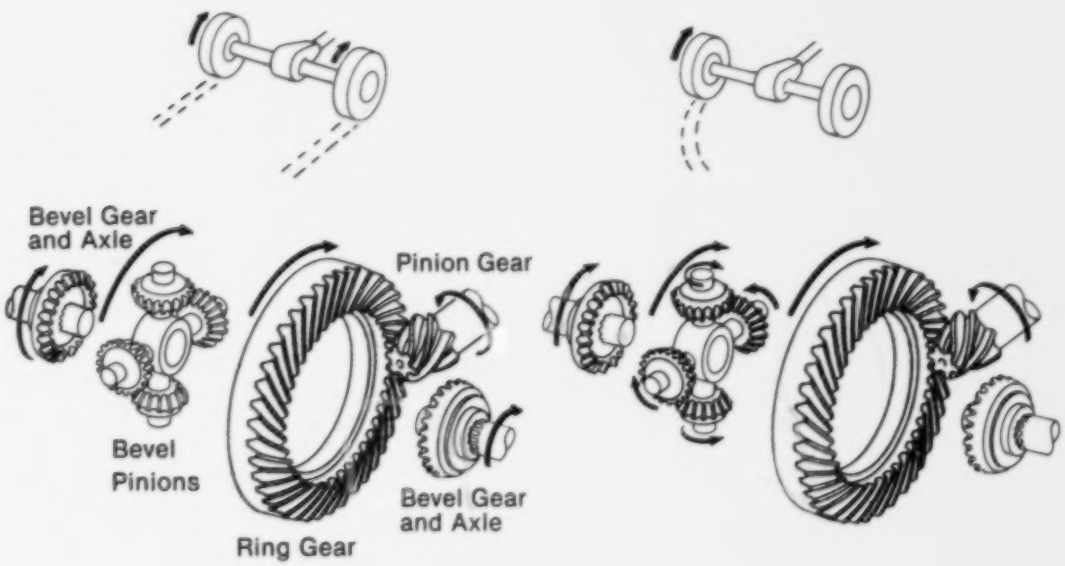
INFORMATION SHEET

VIII. Principle of the differential — Set of gears transmits power to the axles and allows each wheel to travel at a different speed and still propel its own load (Figure 8)

(NOTE: The differential allows both wheels to rotate when machine is moving straight ahead and only one wheel to rotate when the machine turns.)

EXAMPLE:

FIGURE 8



Both Wheels Free to Rotate

One Wheel Free to Rotate

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IX. Types of clutches and their operations

A. Disc — Brings one or more plates together

B. Band — Tightens an outside band over a rotating part

C. Overrunning — Allows engagement in one direction, but the unit free-wheels in the other direction

INFORMATION SHEET

D. Magnetic — Magnetic field holds two parts together, allowing them to rotate as a unit

E. Cone — Engages two cone-shaped parts

F. Expanding-shoe — Expands an inner shoe to contact an outer part

G. Pneumatic — Air activates pack containing a small rubber tube positioned behind a driven member and a fixed member; when valve is opened, air is forced into tube causing it to expand, and thus forcing driven plate against drive plate

(NOTE: Pneumatic clutches provide smooth engagement because the rubber tube absorbs the shock.)

H. Hydraulic — Forces oil into a chamber between the fixed and moving driven members; as oil pressure in the chamber builds, the walls of the chamber are forced outward, causing contact between the driven and drive members

(NOTE: Hydraulic clutches are also fairly shock-proof.)

I. Slip — Works by friction between the drive line and clutch facings

(NOTE: The purpose of the slip clutch is to serve as a safety device in the power train by allowing slippage at moments of excessive demand or shock. During an obstruction, friction force is overcome and clutch slips, thus preventing damage to the machine and power line.)

X. Major types of clutch operating mechanisms

A. Mechanical

(NOTE: Operates by using linkages and springs.)

B. Hydraulic

(NOTE: Operates by hydraulic pressure supplied through a master cylinder and a slave cylinder.)

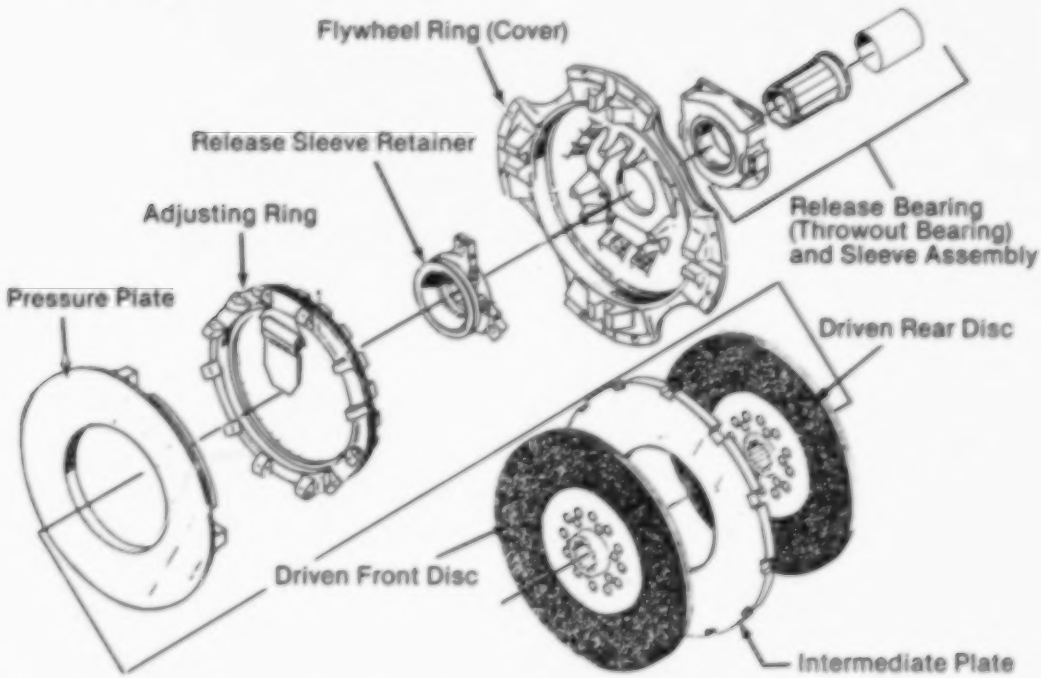
C. Electrical

(NOTE: Operates by electric current through a field coil assembly, rotor unit, faceplate, condenser, and operating switch.)

INFORMATION SHEET

XI. Components of a clutch assembly (Figure 9)

FIGURE 9



Adapted from *Truck and Diesel Repair Manual*. Copyright 1980. Used with permission of the Hearst Corporation.

XII. Clutch operation (Transparency #2)

A. Engaged — Spring pressure clamps the clutch disc between pressure plate and flywheel face

B. Disengaged — Spring pressure released by release bearing and linkage

XIII. Methods used to actuate clutch release (Transparency #3)

A. Mechanical — Links, levers, or rods transfer motion from clutch pedal or control lever to release fork

B. Hydraulic — Master cylinder and slave cylinder transfer motion from clutch pedal or control lever to release fork

INFORMATION SHEET

XIV. Symptoms that may occur when a clutch housing bore has excessive runout

(NOTE: Excessive runout is misalignment in excess of 0.005 inch as compared to center line of transmission shaft.)

A. Excessive transmission gear wear or noise

B. Transmission jumping out of gear

C. Drive line vibration

D. Clutch pedal vibration

E. Scrubby pedal feel

F. Pilot bearing noise

G. Excessive clutch spin time

XV. Clutch malfunctions and probable causes

A. Slipping

(NOTE: Slippage results in failure to transmit full power.)

1. Weak or broken pressure plate spring
2. Worn clutch disc facing
3. Oil or grease contamination
4. Improperly adjusted clutch pedal

B. Dragging

(NOTE: Dragging is failure of clutch to release promptly and fully, thus making gears hard to shift.)

1. Incorrect clutch or pedal adjustment
2. Broken pivots in pressure plate
3. Sticking pilot bearing or bushing
4. Splined disc hub sticking on splined shaft

INFORMATION SHEET

C. Grabbing

(NOTE: Grabbing is violent and sudden engagement.)

1. Oil or grease on clutch disc facing
2. Pressure plate sticking on driving studs
3. Glazed or worn clutch facing
4. Sticking or binding release levers

D. Chattering

(NOTE: Chattering is irregular, rapid, intermittent noise or vibration, especially in low or reverse speeds.)

1. Cracked, warped, or scored pressure plate or flywheel face
2. Wear or looseness in universal joint, differential, or drive axles
3. Worn, loose, or spongy engine mountings
4. Misalignment of power train

E. Binding

(NOTE: Binding is failure to transmit power.)

1. Torn out clutch disc hub
2. Torn off or worn out facings on clutch disc
3. Incorrect adjustment of pressure plate
4. Release bearing dragging on support

F. Noise or rattles

(NOTE: Noise occurs especially at low speeds or when vehicle is on, but standing.)

1. Worn or dry pilot bearing
2. Worn or dry release bearing
3. Pitted clutch shaft bearing or bent clutch shaft
4. Wear in transmission or drive line

INFORMATION SHEET

G. Squeaks

(NOTE: Squeaks occur especially when pedal is depressed.)

1. Clutch release bearing needs lubrication
2. Pilot bearing in flywheel needs lubrication
3. Release sleeve needs lubrication
4. Misalignment

H. Vibrations

(NOTE: Vibration may occur at high or low speeds or periodically.)

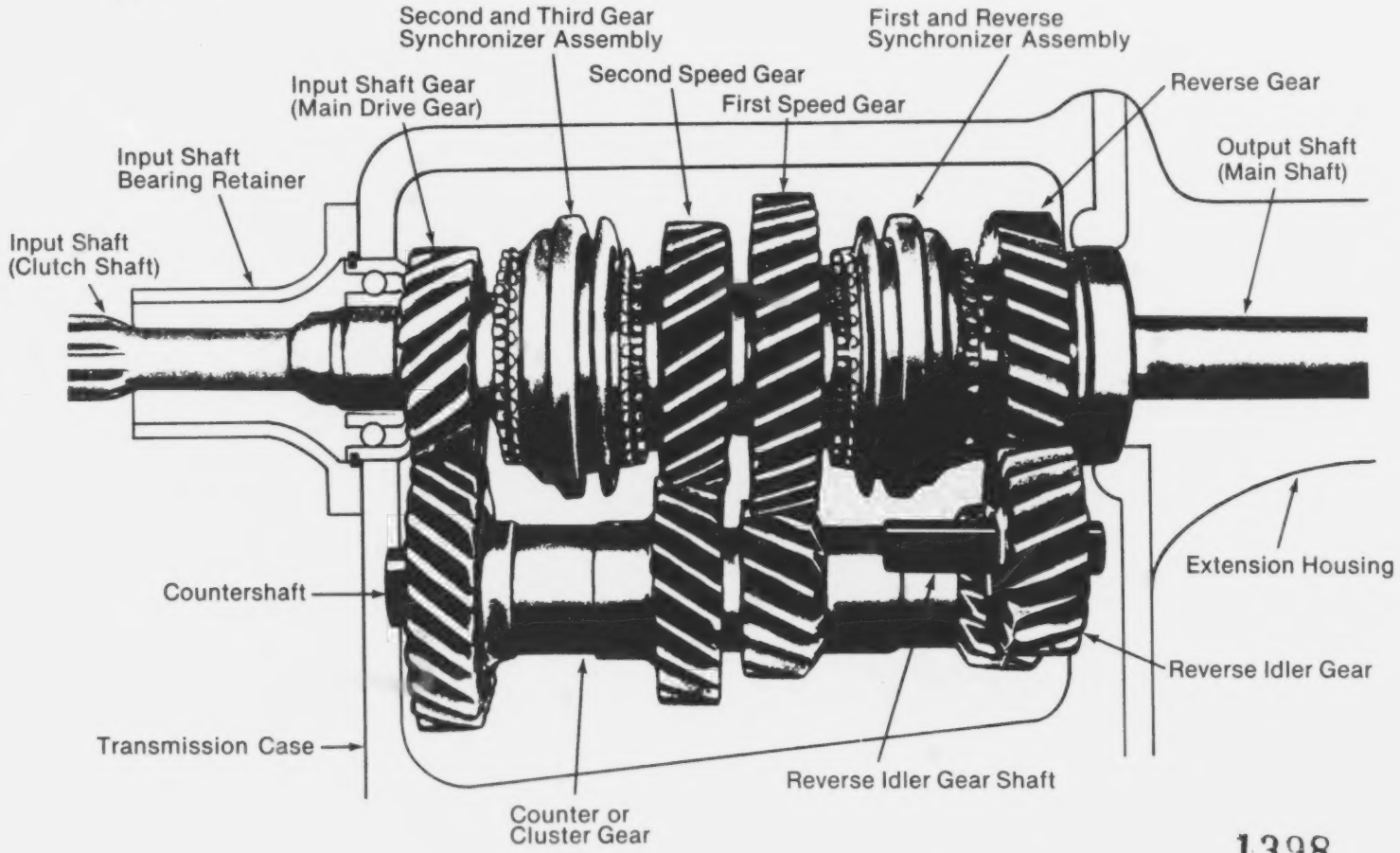
1. Bent clutch shaft
2. Defective clutch disc
3. Dust in clutch
4. Use of rigid disc instead of flexible type

(NOTE: These are only a few of many probable causes. Also note that different problems can have the same causes: oil or grease on the clutch disc can cause slipping, chattering, dragging, or grabbing.)

XVI. Purpose of the transmission — To provide a method of varying the gear ratio between the engine and rear wheels, and to provide reverse movement

XVII. Major parts of a transmission (Figure 10)

FIGURE 10



1397

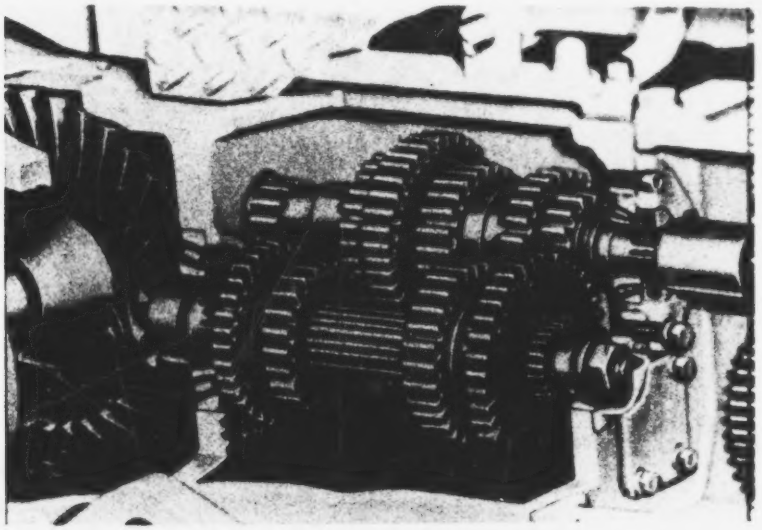
1398

INFORMATION SHEET

XVIII. Major types of mechanical transmissions (Figures 11-13)

A. Sliding gear

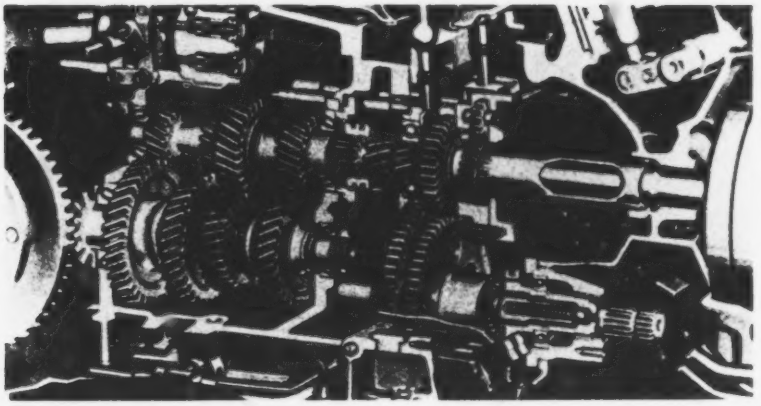
FIGURE 11



Courtesy of Deere and Company, Moline, Illinois.

B. Collar shift

FIGURE 12



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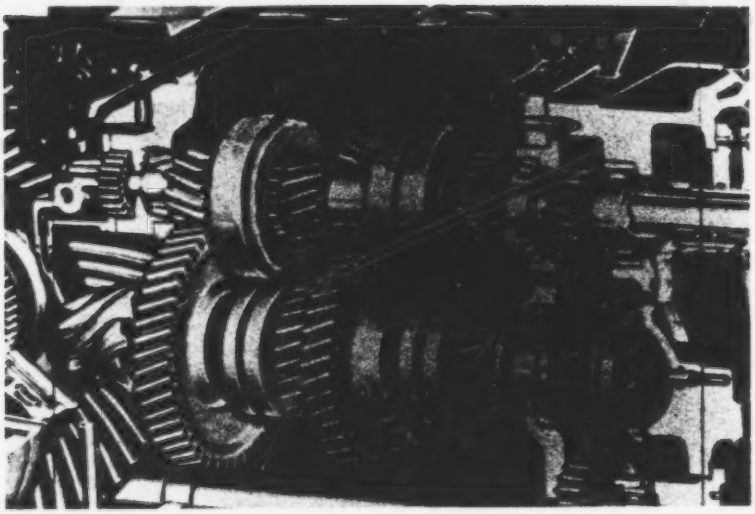
INFORMATION SHEET

C. Synchromesh

FIGURE 13



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XIX. Common types of synchronizers

A. Block

B. Disc and plate

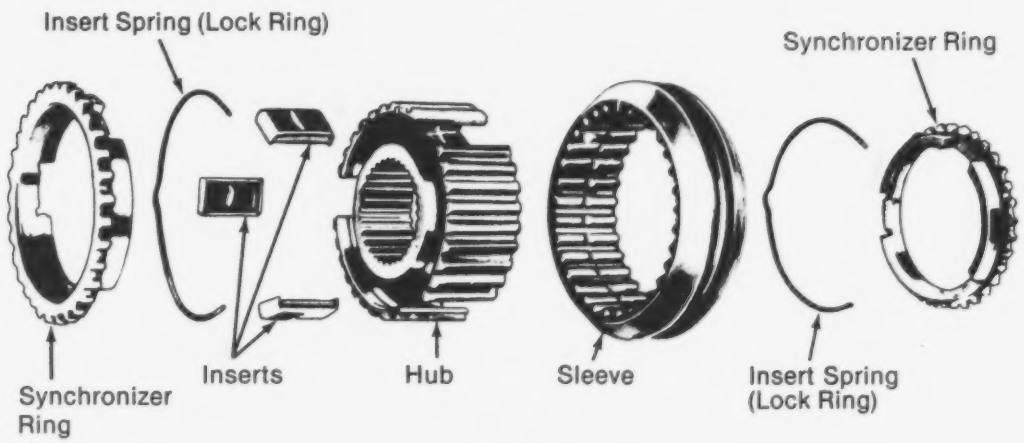
C. Plain

D. Pin

INFORMATION SHEET

XX. Parts of a typical synchronizer (Figure 14)

FIGURE 14



XXI. Operation of a three-speed synchromesh transmission (Transparencies #4-#8)

A. Neutral — Input shaft drives cluster gear, which in turn drives constant mesh second and reverse idler gears; no power is transmitted

B. First gear — First and reverse synchronizer sleeve moves to engage first gear; input shaft transmits power to cluster gear, to first gear, and on to output shaft

C. Second gear — Second and third gear synchronizer sleeve moves to engage second gear; input shaft transmits power to cluster gear, to second gear, and on to output shaft

D. Third gear — Second and third gear synchronizer sleeve moves to engage third gear; input shaft transmits power to output shaft

E. Reverse gear — First and reverse synchronizer sleeve moves to engage reverse idler gear; input shaft transmits power to cluster gear; cluster gear drives reverse idler gear; reverse idler gear drives reverse gear and output shaft in direction opposite engine rotation

XXII. Hydraulic assist transmission — A train of gears that can be shifted without interrupting the flow of power, which is controlled by hydraulic clutches

INFORMATION SHEET

XXIII. How hydraulic clutches and gear trains work together

A. Hydraulic clutches — Control power flow

B. Gear trains — Transmit power flow

XXIV. Basic types of gear sets used in hydraulic-assist transmissions

A. Countershaft

B. Planetary

XXV. Basic parts of a planetary gear system

(NOTE: A planetary gear system is an assembly of gears whose organization resembles the solar system. See Figure 15.)

A. Sun gear

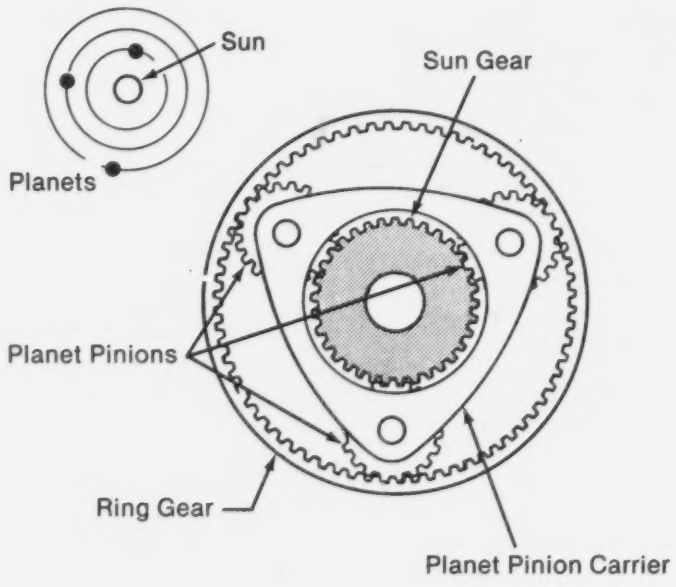
B. Ring gear

C. Planet pinions

D. Planet pinion carrier

EXAMPLE:

FIGURE 15



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INFORMATION SHEET

XXVI. Jobs that oil performs in a hydraulic-assist transmission (Transparency #9)

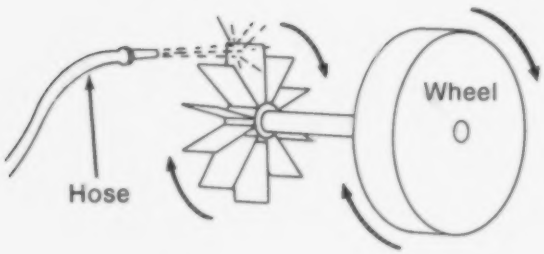
A. Lubricates and cools clutches and brakes

B. Engages clutches and brakes

XXVII. Basic types of hydraulic transmissions (Figures 16 and 17)

A. Hydrodynamic

FIGURE 16



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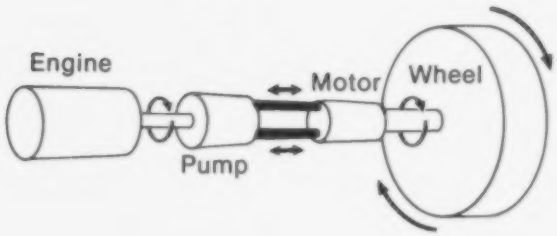
B. Hydrostatic

FIGURE 17



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XXVIII. Factors that control operation of hydrostatic drive

A. Rate of oil flow — Gives the speed

INFORMATION SHEET

B. Direction of oil flow — Gives the direction

C. Pressure of oil — Gives the power

(NOTE: These three factors provide infinite control, giving endless selections of speed and torque in a hydrostatic drive.)

XXIX. Advantages of hydrostatic drives

A. Provide infinite speeds and torque

B. Allow smooth shifting without "steps"

C. Have easy one-lever control

D. Can be shifted "on the go"

E. Provide high torque for starting

F. Have flexible location; no drive lines

G. Are compact in size for big power

H. Have no clutches or large gear trains

I. Reduce shock loads

J. Require low maintenance and service

XXX. Differences between hydrostatic drives and torque converters

A. Hydrostatic drives — Driven by fluids at high pressure but at relatively low speeds

B. Torque converter — Driven by fluids at low pressure but at high speeds

XXXI. Difference between a torque converter and a fluid coupling

A. Torque converter — Can multiply the torque it receives

B. Fluid coupling — Can only transmit torque

XXXII. Jobs that oil performs in a hydraulic control system

A. Oil flow lubricates and cools parts

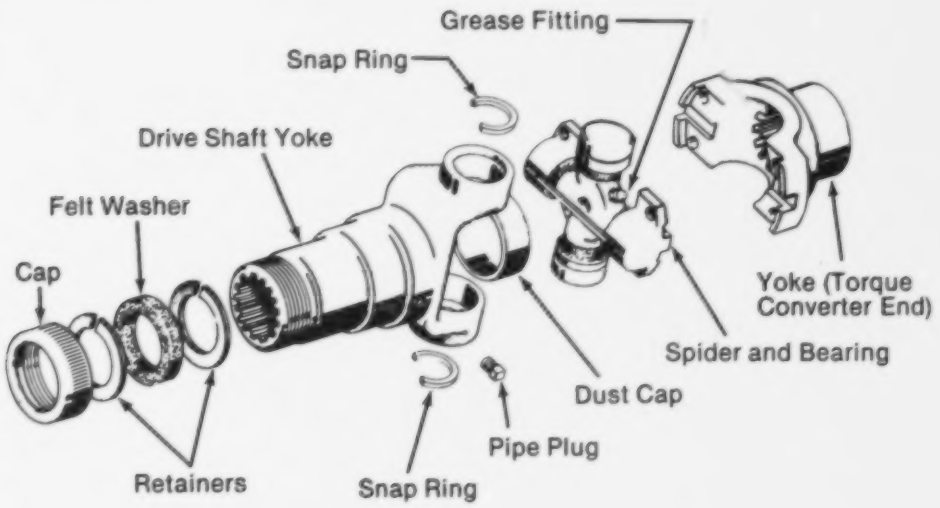
B. Oil pressure engages clutches

C. Oil velocity drives turbines

INFORMATION SHEET

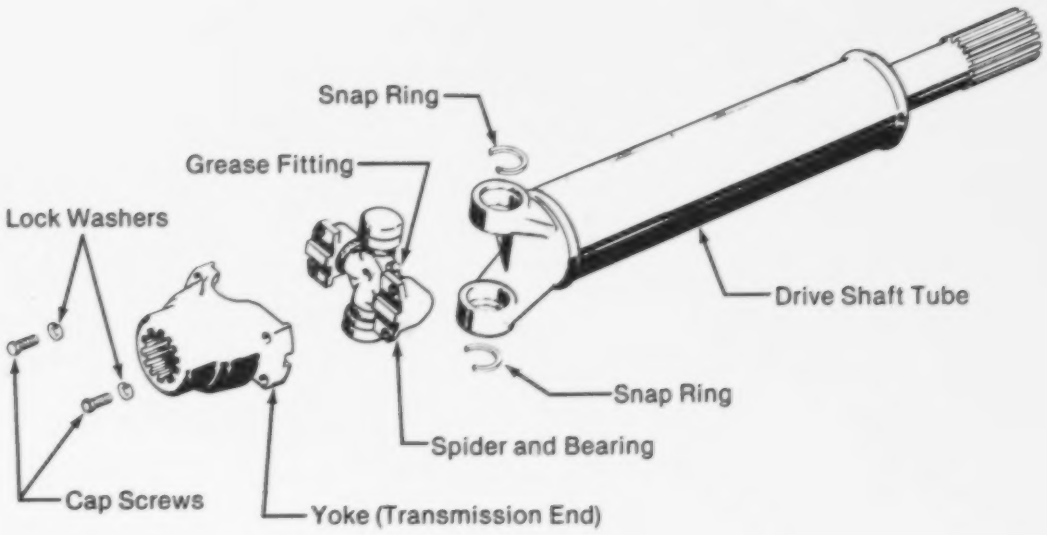
XXXIII. Components of a drive (propeller) shaft (Figures 18 and 19; Transparencies #10 and #11)

FIGURE 18



Adapted with permission of JI Case, a Tenneco Company.

FIGURE 19



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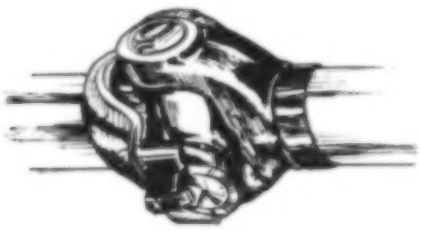
INFORMATION SHEET

XXXIV. Types of U-joints (universal joints) (Figures 20-23)

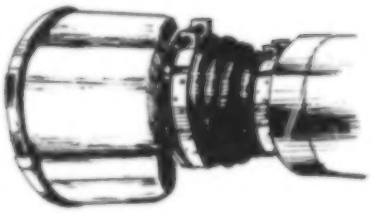
A. Cross-and-roller

FIGURE 20



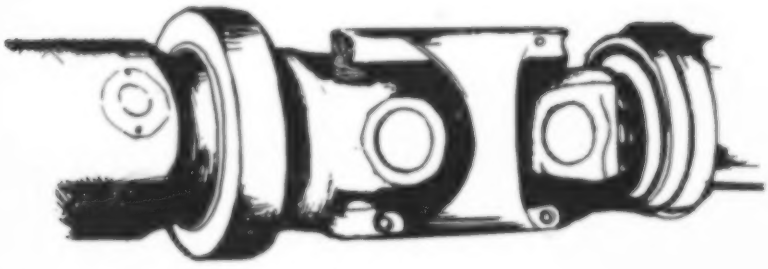
B. Ball-and-trunnion

FIGURE 21



C. Constant velocity

FIGURE 22

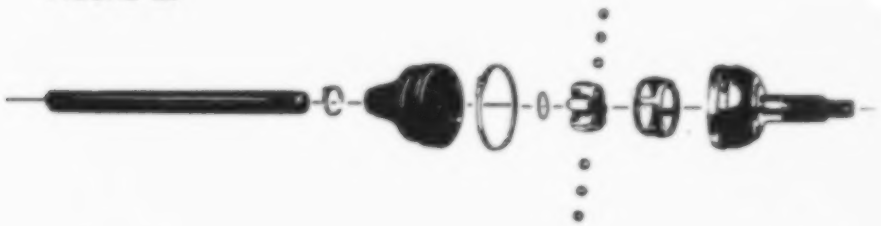


INFORMATION SHEET

D. Rzeppa

(NOTE: The rzeppa is mainly used on front-wheel drives.)

FIGURE 23



XXXV. Methods of controlling drive-line vibration (Transparency #12)

A. Vibration absorber

B. Constant velocity U-joint

C. Torsional vibration damper

D. Elastomer-sleeved propeller shaft

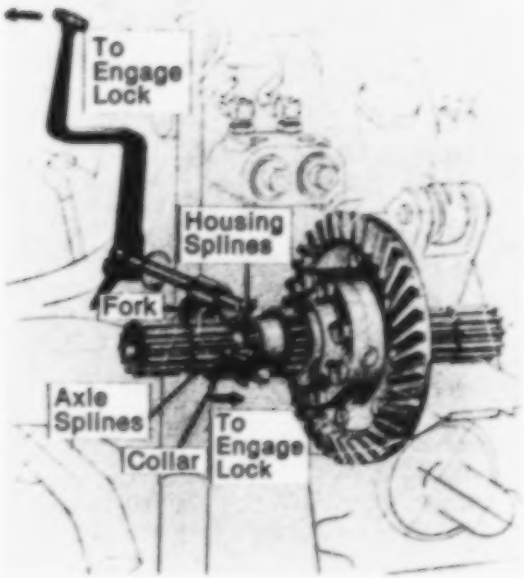
XXXVI. How differential locks are used — When one wheel loses resistance on slick ground and starts spinning, the differential lock directs power equally to both wheels by locking the two axles together

INFORMATION SHEET

XXXVII. Types of differential locks (Figures 24-26)

A. Mechanical

FIGURE 24

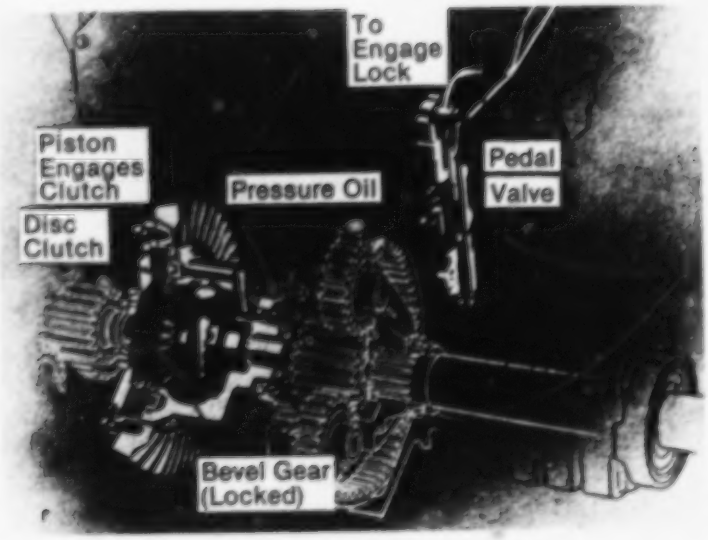


Courtesy of Deere and Company, Moline, Illinois.

INFORMATION SHEET

B. Hydraulic

FIGURE 25



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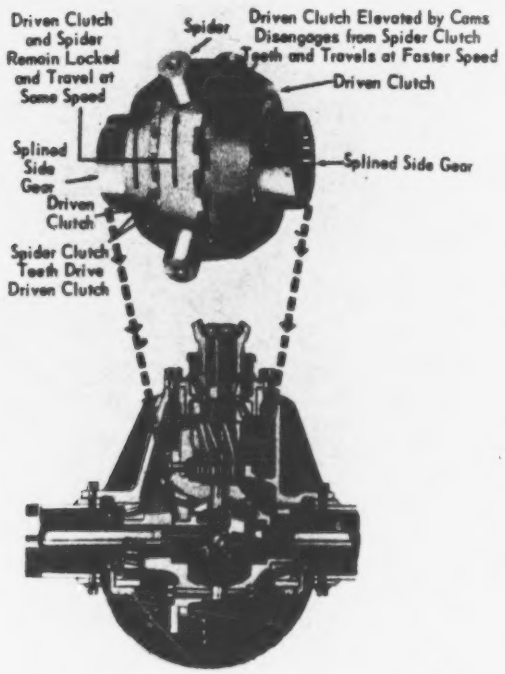
INFORMATION SHEET

C. Automatic (no-spin)

FIGURE 26


Driven Clutch and Spider Remain Locked and Travel at Same Speed
Spider
Driven Clutch Elevated by Cams Disengages from Spider Clutch Teeth and Travels at Faster Speed
Driven Clutch
Splined Side Gear
Splined Side Gear Driven Clutch
Spider Clutch Teeth Drive Driven Clutch

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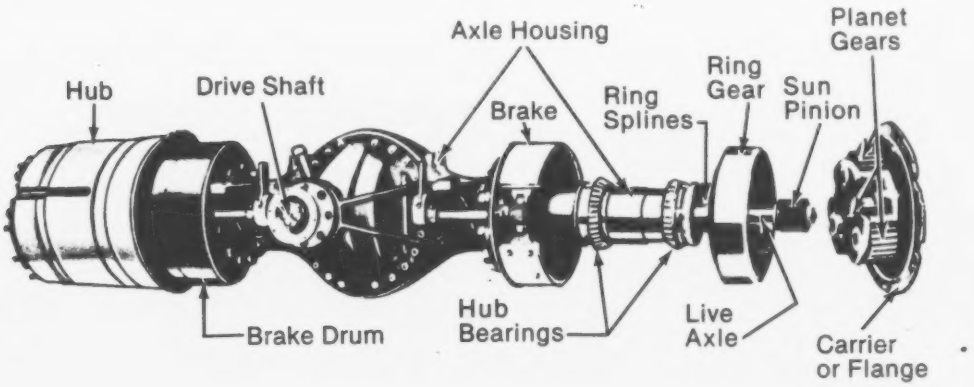
INFORMATION SHEET

XXXVIII. Final drive — Last phase of the power train; gives final reduction in speed and increase in torque to drive wheels (Figure 27)

(NOTE: By reducing speed, the final drive lowers the stress and simplifies the transmission, because extra gears and shafts can be eliminated.)

EXAMPLE: Axle housing and final drive

FIGURE 27



Source: Euclid, Inc., Cleveland, Ohio.

XXXIX. Major types of final drive systems

A. Straight axle

B. Pinion

C. Planetary

D. Chain

XL. Difference between live and dead axle

A. Live axle — Transmits engine torque as well as supporting part of machine's weight

B. Dead axle — Only supports machine

XLI. Types of rear axle bearings (Transparencies #13-#15)

A. Ball

(NOTE: This bearing is prelubricated and sealed; do not wash in solvent.)

INFORMATION SHEET

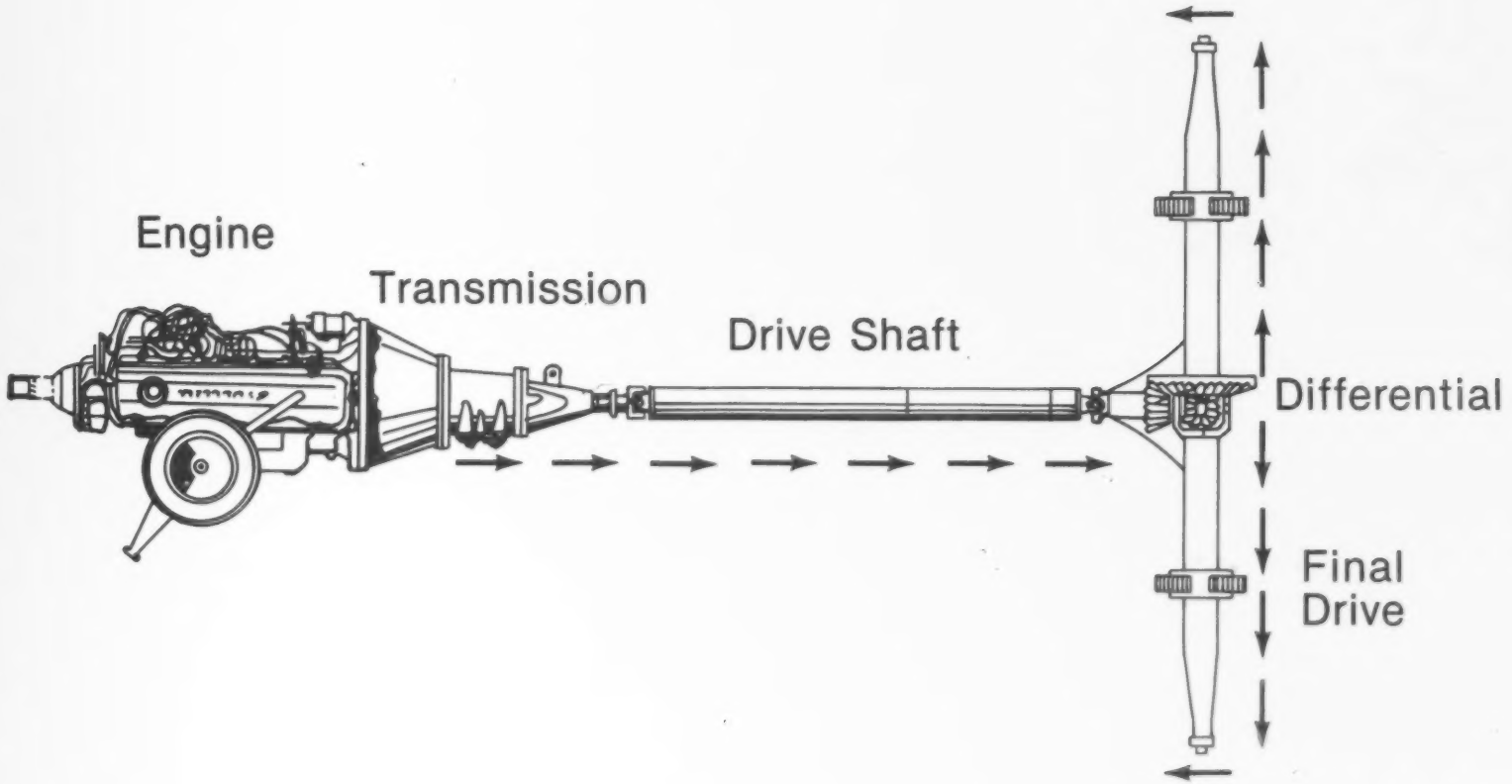
B. Tapered roller

(NOTE: This bearing must be packed with lubricant during installation.)

C. Flat roller

(NOTE: This bearing is lubricated from the differential.)

Parts of a Power Train



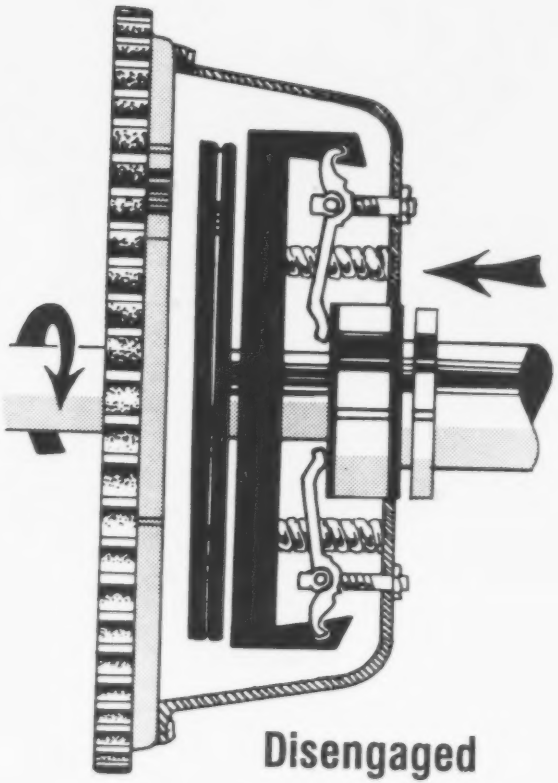
1413

1414

TM #1

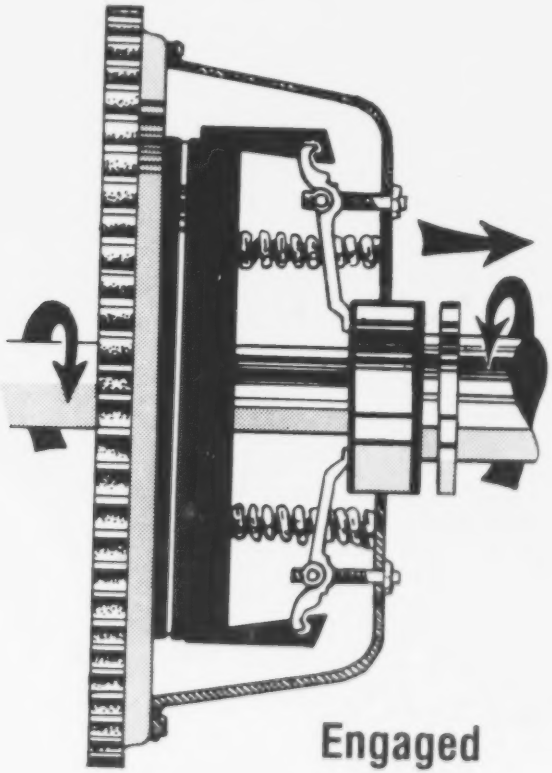
HEM - 37-E

Clutch Operation



Disengaged

1415



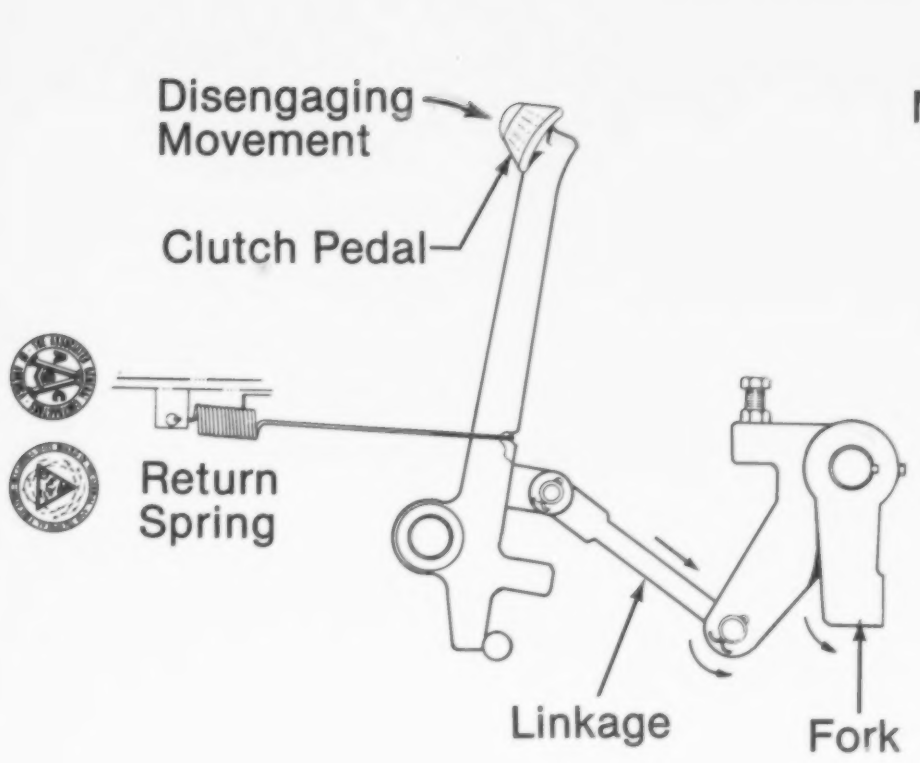
Engaged

1416

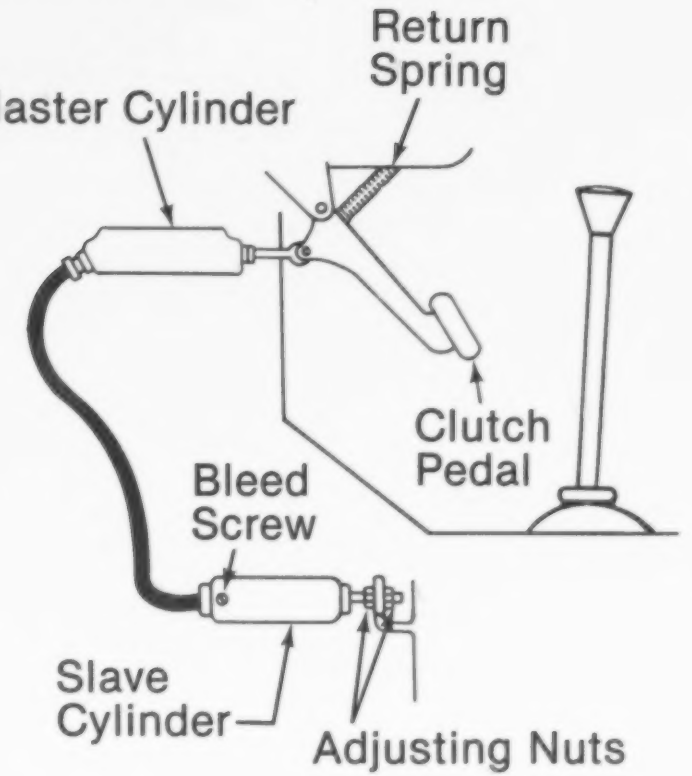
TM #2

HEM - 39-E

Clutch Controls



Mechanical



Hydraulic

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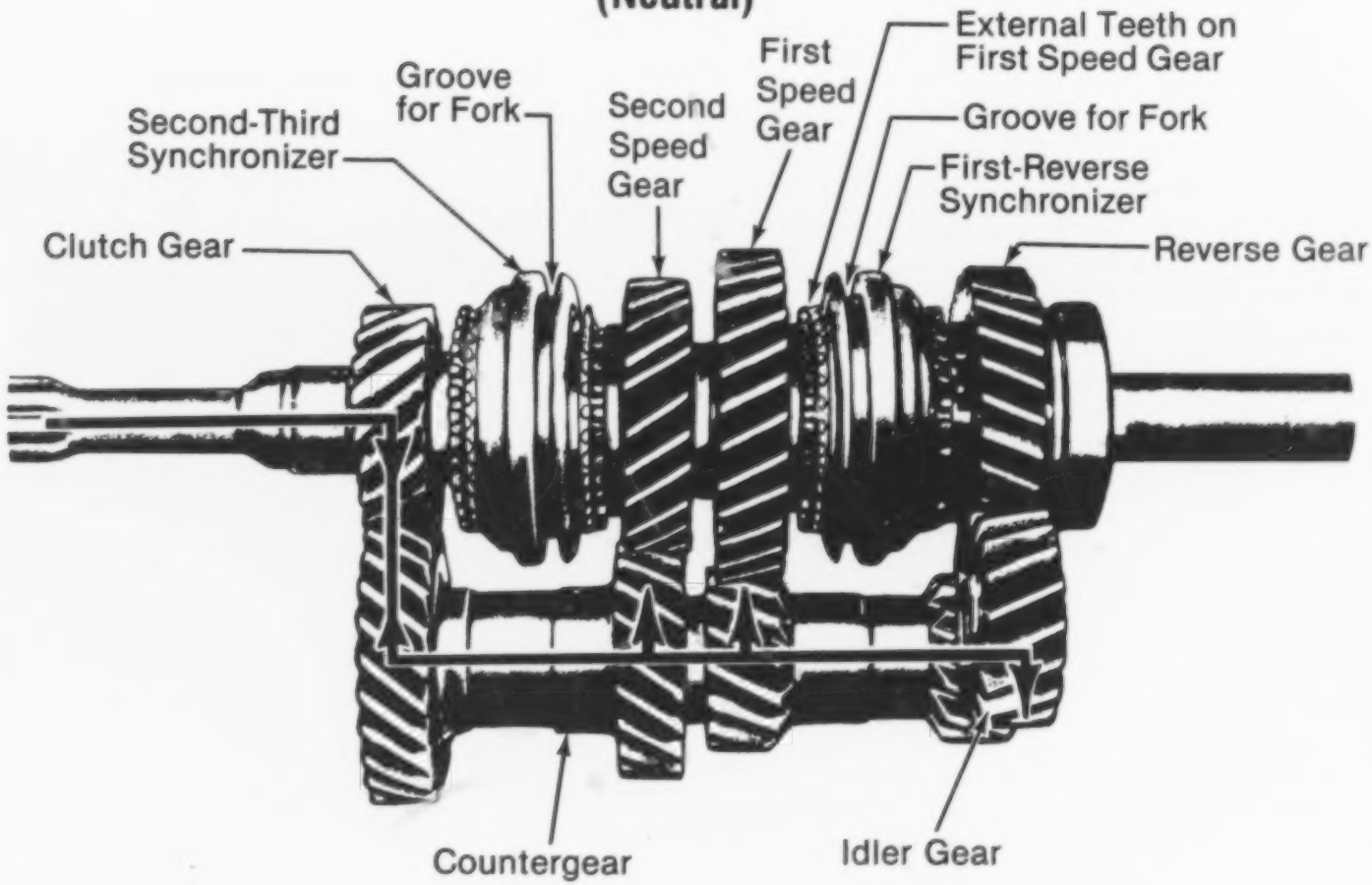
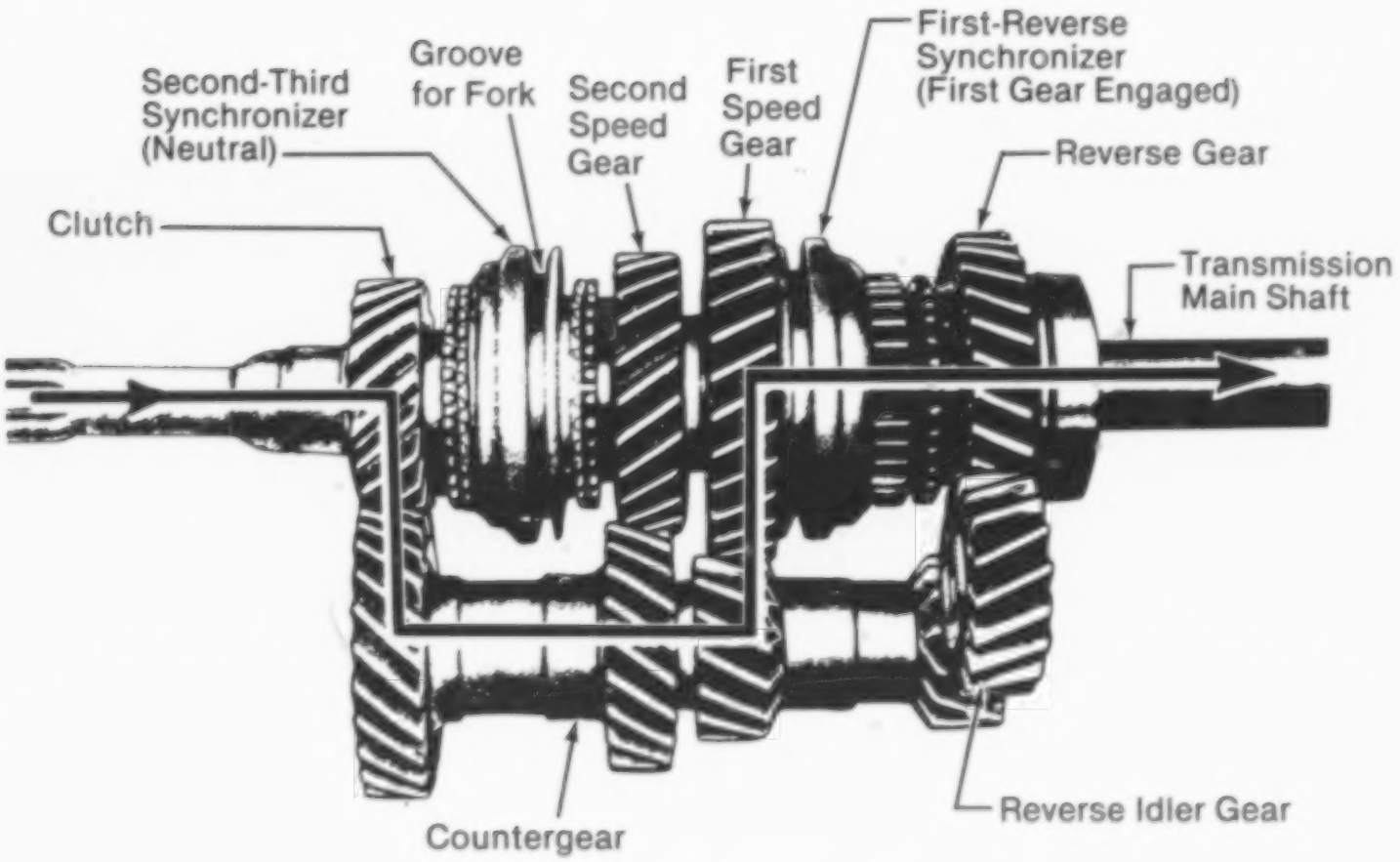
Transmission Operation

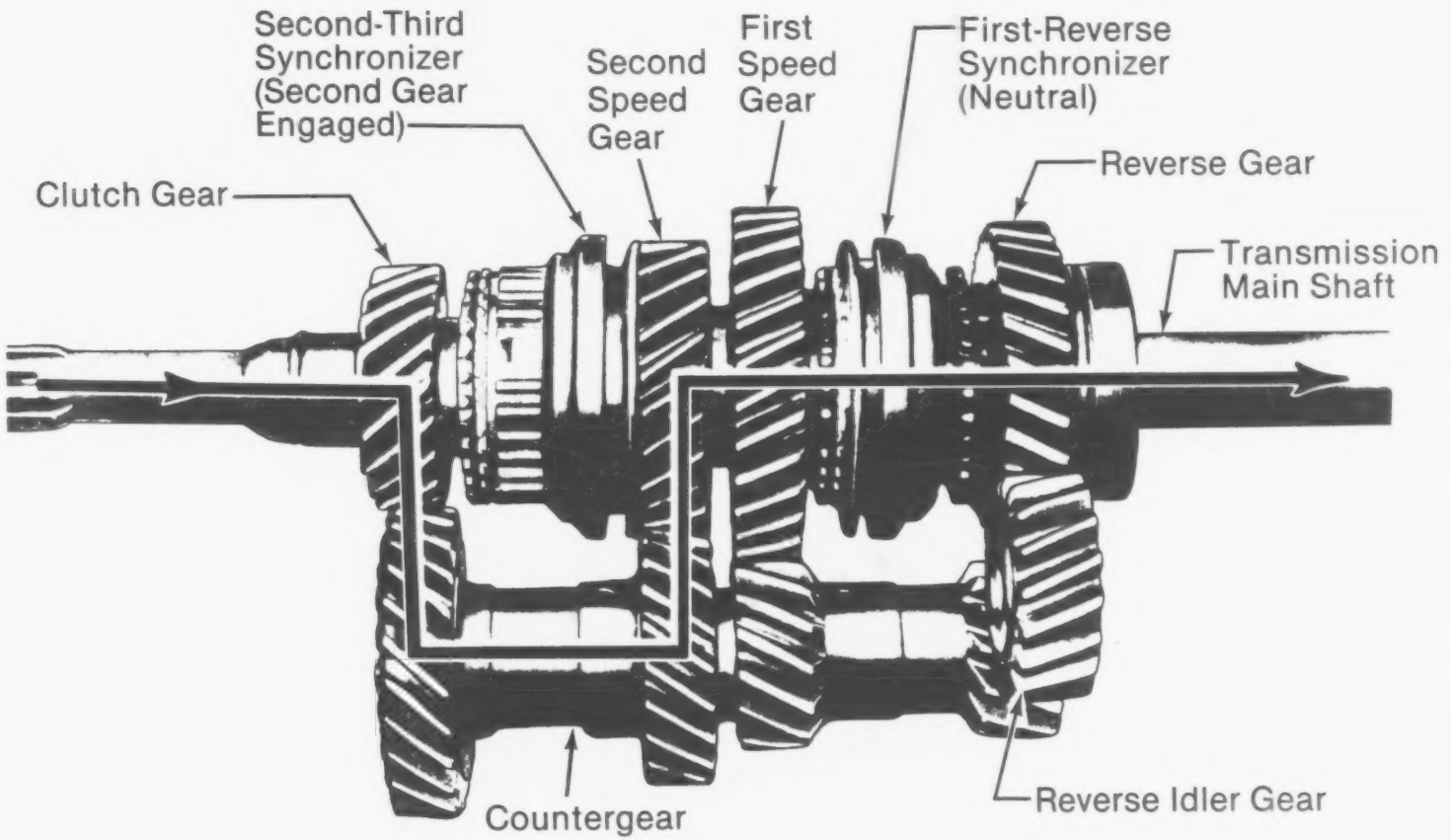
(Neutral)



Transmission Operation
(First Gear)



Transmission Operation
(Second Gear)



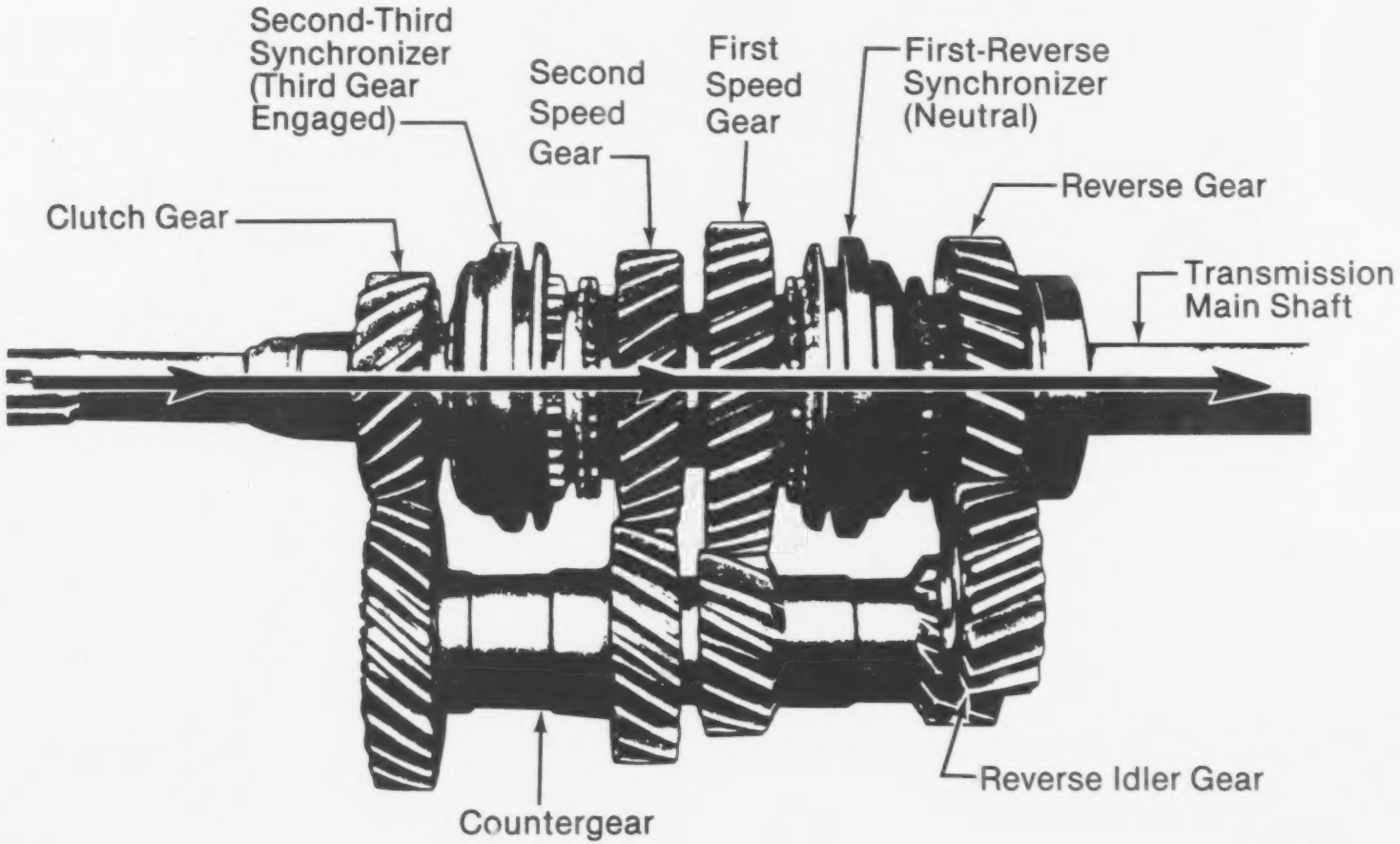
1423

1424

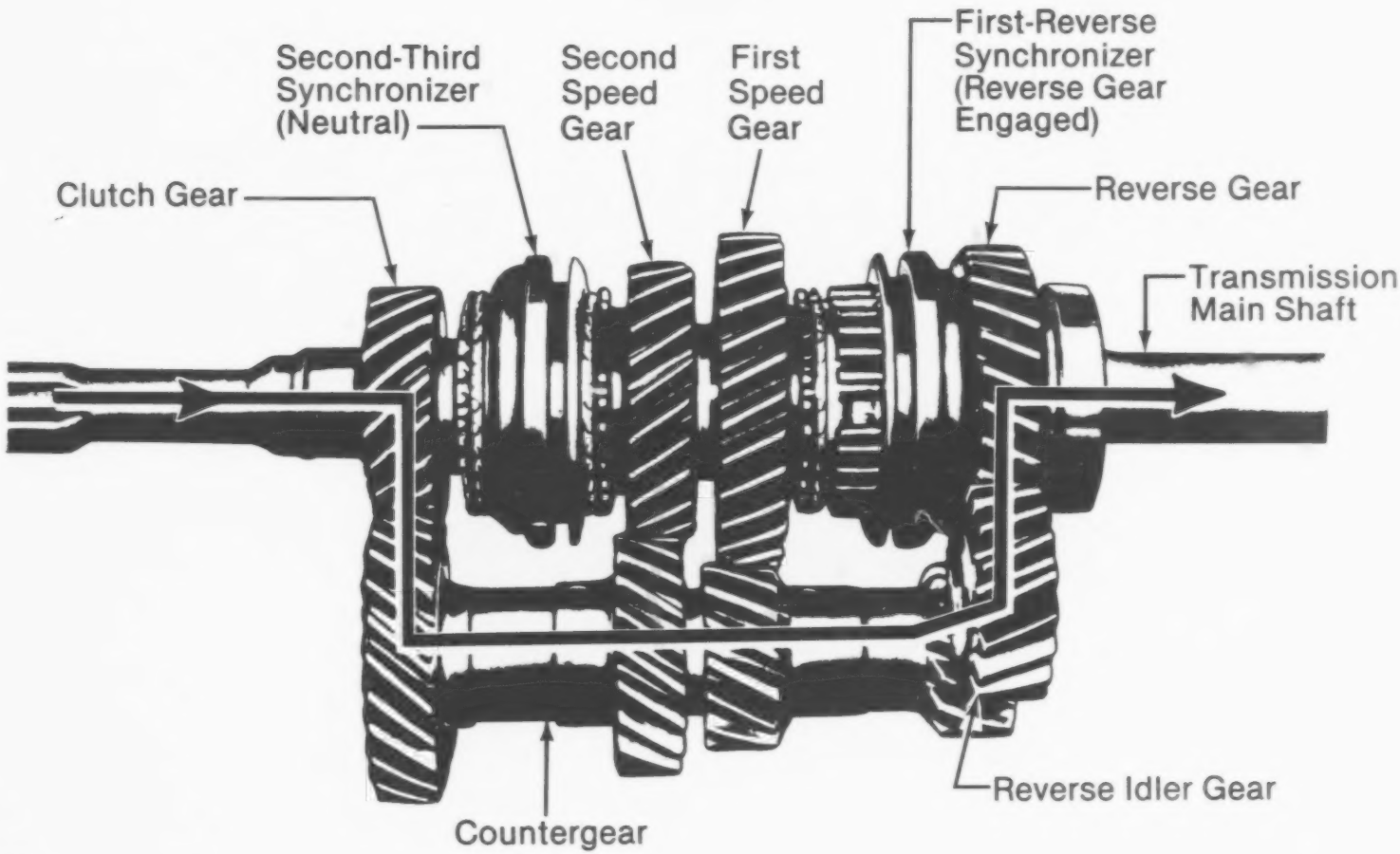
TM #6

HEM - 47-E

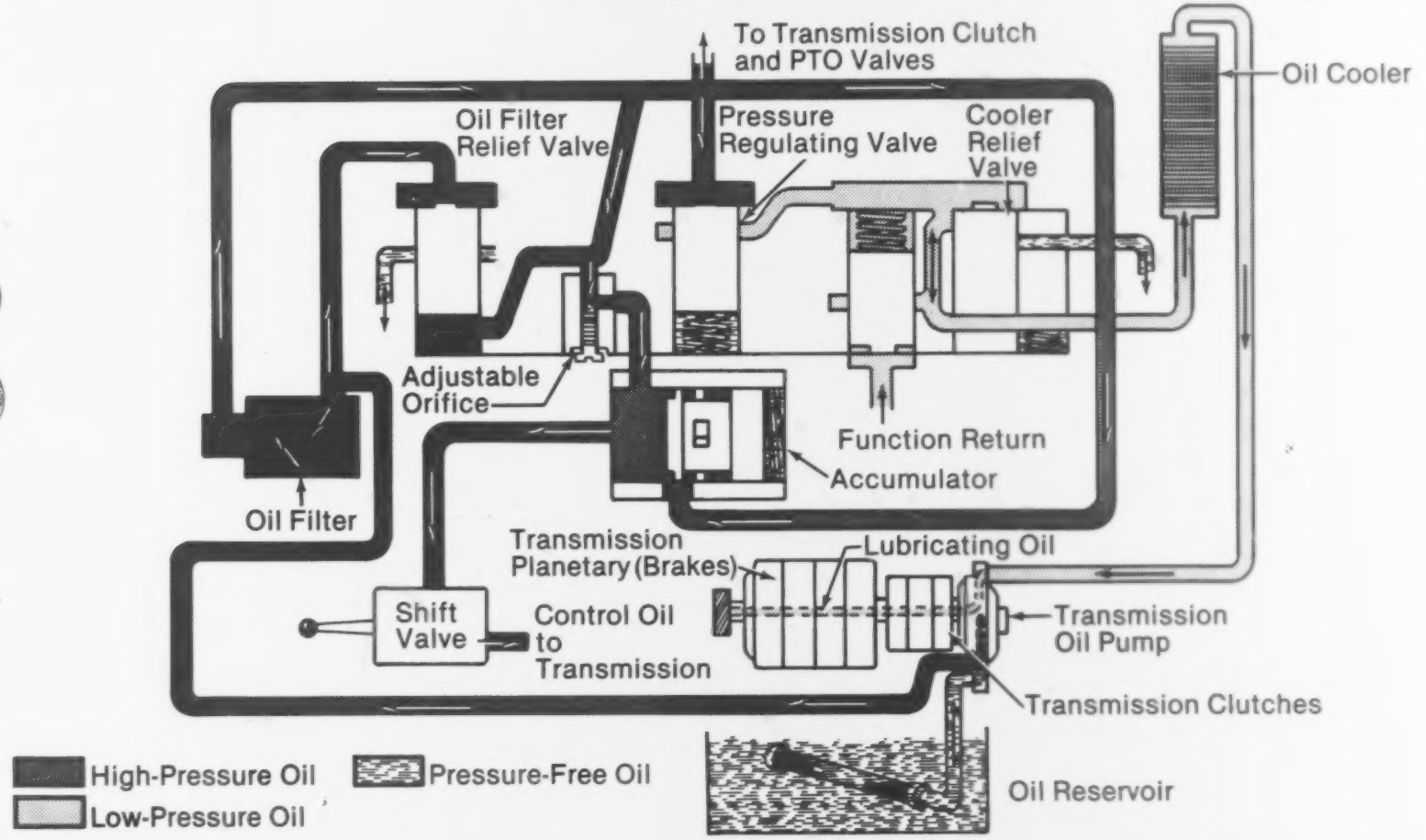
Transmission Operation
(Third Gear)



Transmission Operation
(Reverse)



Hydraulic Oil Circuit for Typical Hydraulic-Assist Transmission



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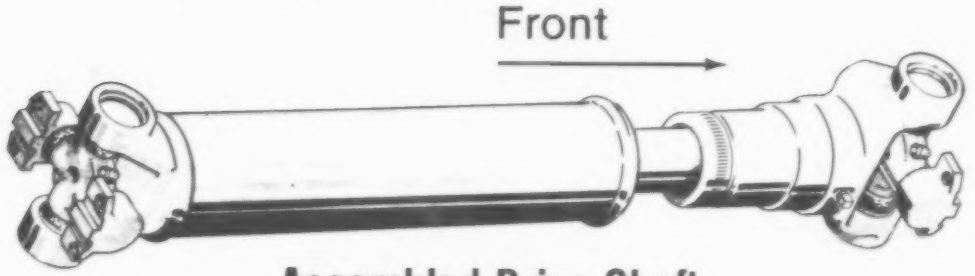
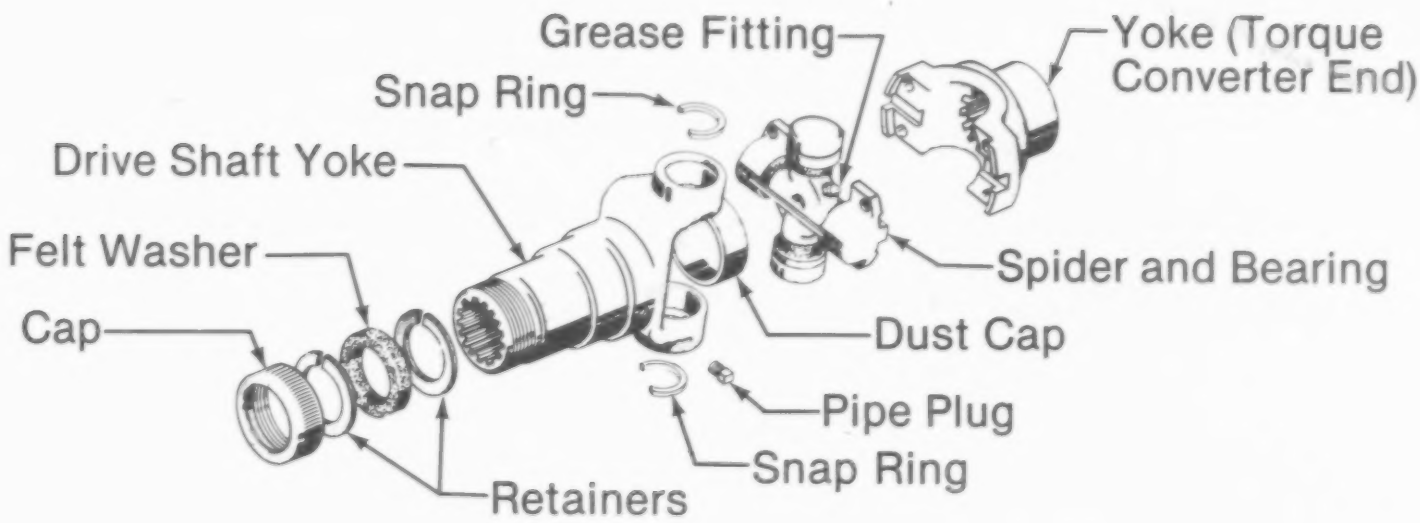
Drive (Propeller) Shaft Components



Assembled Drive Shaft



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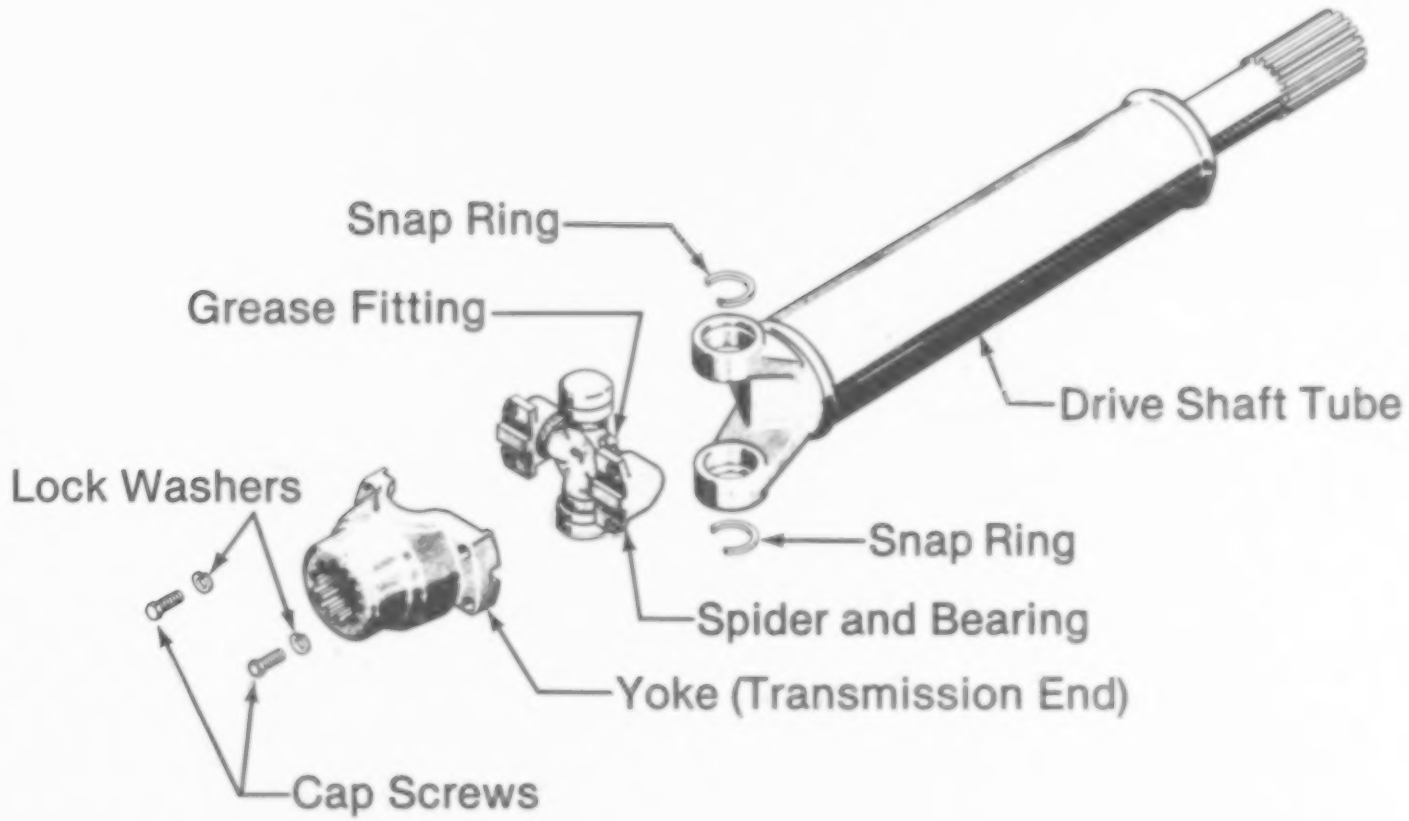
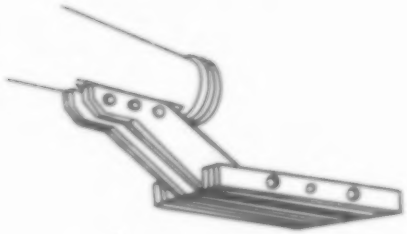
Drive (Propeller) Shaft Components
(Continued)



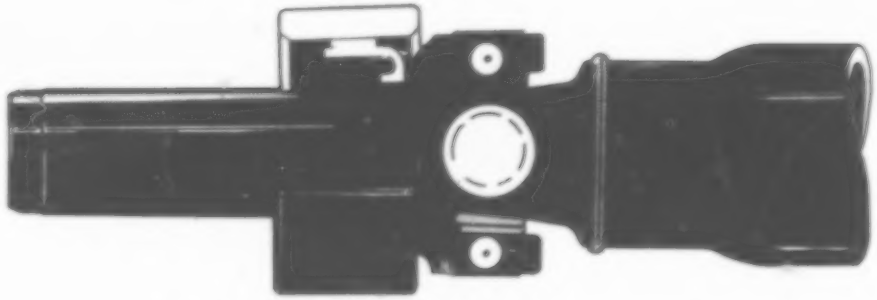
Adapted wtih permission of J I Case, a Tenneco Company.

Methods of Controlling Drive Line Vibration



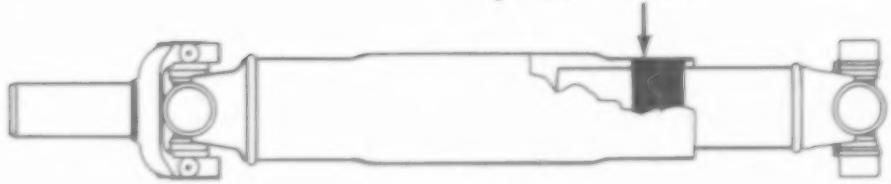
Vibration Absorber

Constant Velocity U-Joint



Torsional Vibration Damper

Elastomer-Sleeved
Propeller Shaft



1435

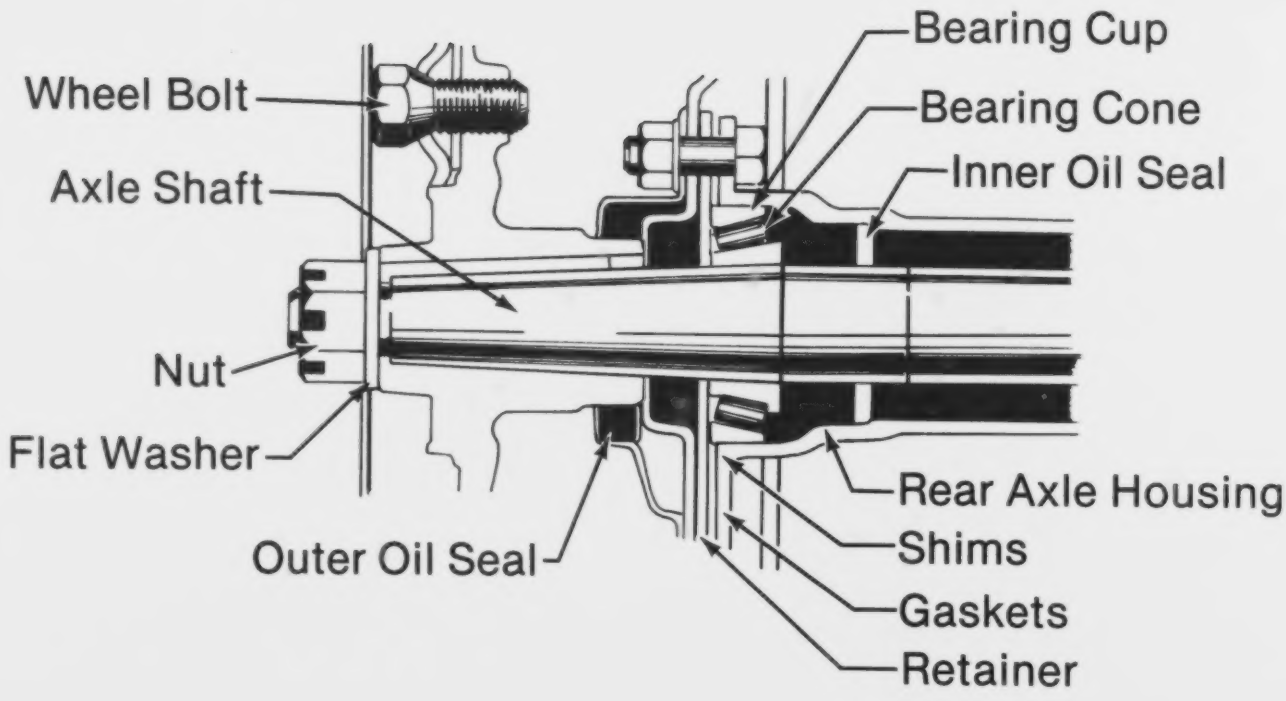
1436

TM #12

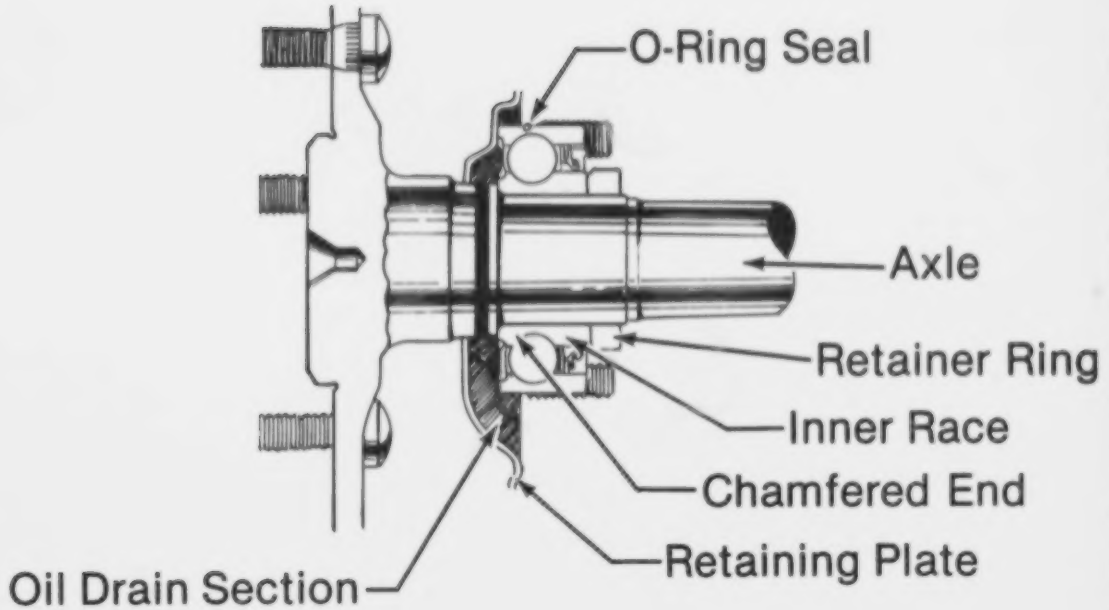
HEM - 59E

A5
100 mm
1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0
1.0 mm
1.5 mm
2.0 mm
ABCDEFGHIJKLMNOPQRSTUVWXYZ
abcdefghijklmnopqrstuvwxyz
1234567890

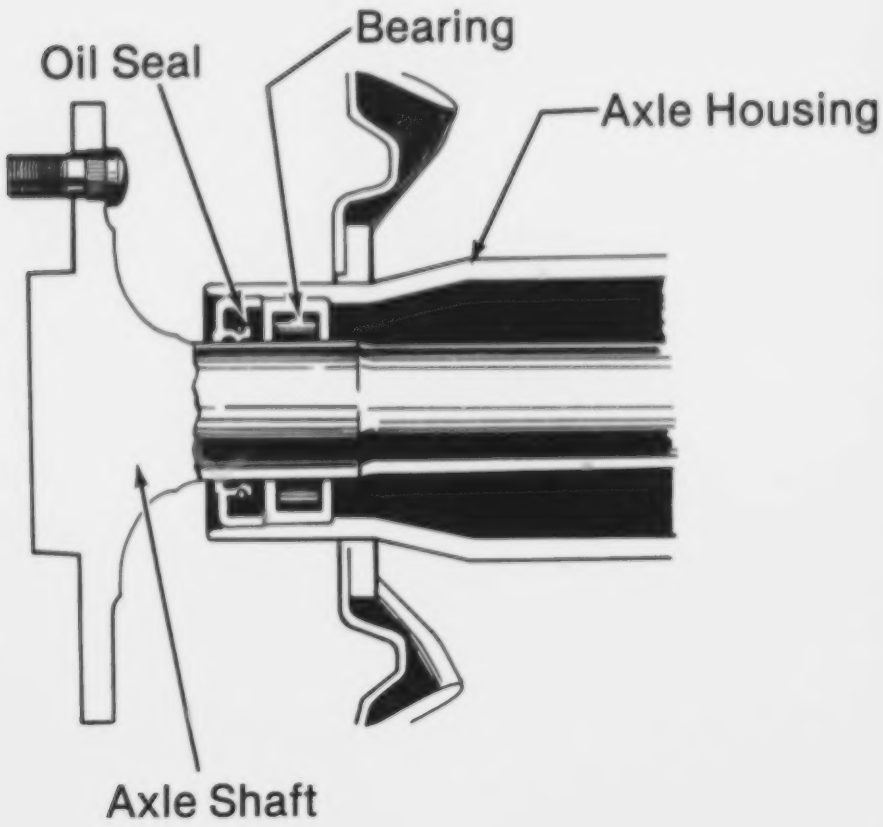
Tapered Roller Rear Axle Bearing



Ball-Type Rear Axle Bearing



Flat Roller Rear Axle Bearing



POWER TRAINS
UNIT I

JOB SHEET #1 — ADJUST CLUTCH LINKAGE FREE TRAVEL

I. Equipment and materials

A. Vehicle with manual transmission

B. Basic hand-tool set

C. Floor jack

D. 4 jack stands

E. Droplight

F. Creeper

G. Safety glasses

H. Appropriate service manual

II. Procedure

(NOTE: Be sure to wear safety glasses if it is necessary to work under vehicle.)

A. Make sure that clutch pedal returns firmly against pedal bumper when released

B. Jack up vehicle and support on jack stands

C. Locate adjustment on clutch linkage

(NOTE: On some vehicles, the clutch adjustment is made in the engine compartment.)

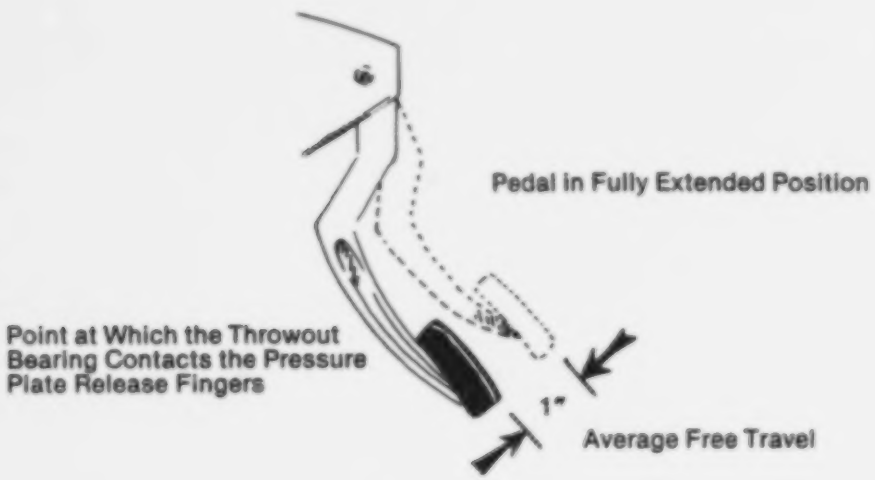
D. Check clutch linkage for binding

JOB SHEET #1

E. Adjust clutch linkage until desired free travel is obtained (Figure 28)

(NOTE: Adjust linkage to manufacturer's specifications. Usually, about 1 inch of clutch pedal free travel is desired.)

FIGURE 28


Pedal in Fully Extended Position
Point at Which the Throwout Bearing Contacts the Pressure Plate Release Fingers
1"
Average Free Travel

F. Secure locknut on adjuster if vehicle is so equipped

G. Remove jack stands and lower vehicle to floor

H. Clean work area; clean and put away all tools and equipment

POWER TRAINS
UNIT I

JOB SHEET #2 — REMOVE A CLUTCH ASSEMBLY

I. Equipment and materials

- A. Vehicle with manual transmission
- B. Floor jack
- C. 4 jack stands
- D. Basic hand-tool set
- E. Battery cable pliers
- F. Extra drive shaft slip-joint yoke
- G. Transmission jack
- H. Engine support tool
- I. Suitable wood blocks, 2" x 4" x 6"
- J. Droplight
- K. Creeper
- L. Shop towels
- M. Safety glasses

II. Procedure

- A. Disconnect ground battery cable
- B. Jack up vehicle and support with jack stands
- C. Mark drive shaft for reinstallation
- D. Remove drive shaft
- E. Place extra slip-joint yoke on transmission output shaft
- F. Secure rollers on drive shaft with tape
- G. Disconnect transmission shift linkage

(NOTE: It may be necessary to support the rear of the engine before transmission removal if the transmission has a rear engine mount attached.)

JOB SHEET #2

H. Disconnect rear mount

I. Use jack to raise transmission just enough to clear crossmember

J. Remove crossmember if necessary

(CAUTION: As the transmission is lowered, the distributor cap, radiator hoses, or fan blades could be damaged by interfering with stationary parts.)

K. Lower transmission and support rear of engine

L. Remove dust cover from clutch housing if housing is so equipped

M. Remove transmission attaching bolts

(CAUTION: Use a transmission jack of some type for removal of transmission.)

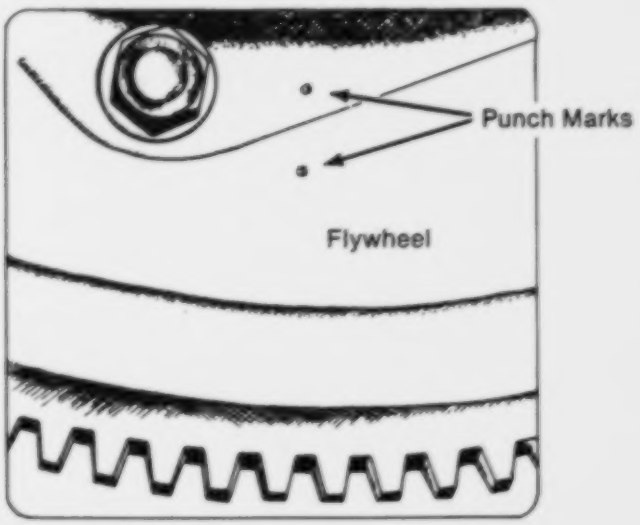
N. Remove transmission

O. Remove clutch release bearing

P. Remove clutch housing

Q. Mark flywheel and pressure plate with a center punch while clutch assembly is exposed (Figure 29)

FIGURE 29



JOB SHEET #2

R. Place a bar through the clutch disc and pressure plate

(NOTE: The bar is placed through the clutch disc and pressure plate to prevent them from falling as the attaching bolts are removed.)

S. Remove pressure plate attaching bolts

T. Remove clutch and pressure plate

U. Clean work area; clean and put away all tools and equipment

POWER TRAINS
UNIT I

JOB SHEET #3 — INSPECT A CLUTCH ASSEMBLY

I. Equipment and materials

A. Vehicle with manual transmission

B. Solvent container

C. Solvent

D. Brush

E. Droplight

F. Shop towels

G. Safety glasses

II. Procedure

A. Wash pressure plate and clutch housing in suitable solvent

(CAUTION: Do not wash release bearing in solvent. Solvent will wash out the lubricant and ruin the bearing. Do not wash clutch disc in solvent. Solvent will damage the facings.)

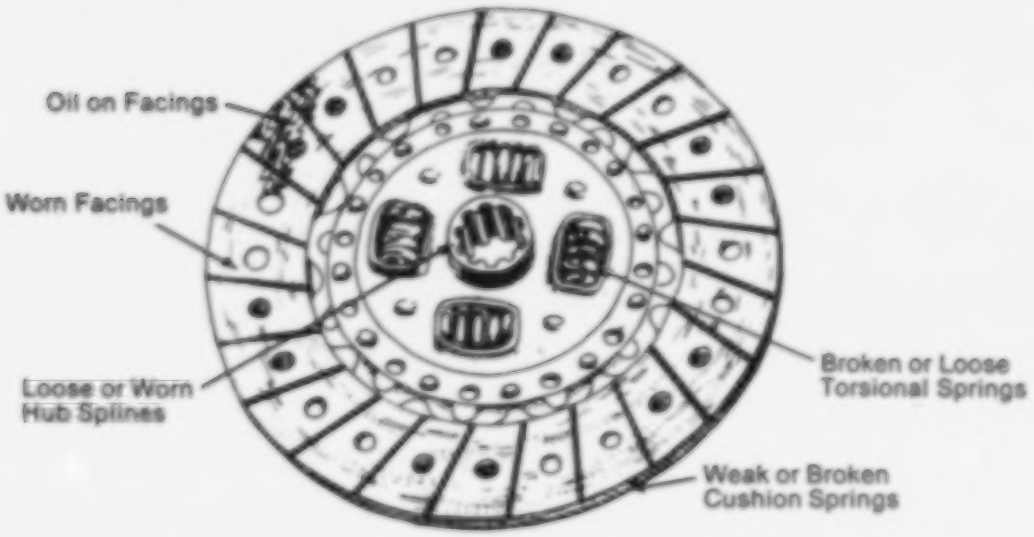
B. Inspect flywheel for scoring and roughness

C. Inspect pressure plate for scoring, roughness, and broken springs

JOB SHEET #3

D. Inspect clutch disc for wear or damage (Figure 30)

FIGURE 30



E. Inspect clutch release bearing for excessive wear on contact face; check for roughness of balls and races

F. Clean work area; clean and put away all tools and equipment

POWER TRAINS
UNIT I

JOB SHEET #4 — CHECK CLUTCH HOUSING ALIGNMENT

I. Equipment and materials

A. Transmission and clutch assembly (removed from vehicle)

B. Basic hand-tool set

C. Dial indicator set

D. Safety glasses

E. Clean shop towels

F. Torque wrench

G. 3-inch bolt

II. Procedure

(NOTE: This procedure is accomplished with the transmission and clutch assembly removed. The clutch housing bore and transmission mating surface should be clean.)

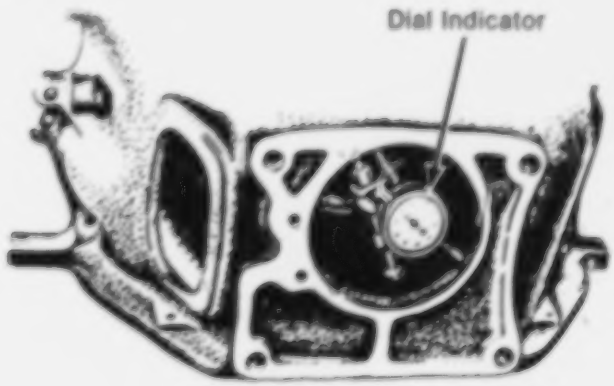
A. Check bore runout

1. Replace one flywheel-to-crankshaft bolt with a bolt about 3 inches long

2. Mount dial indicator on this bolt (Figure 31)

(NOTE: The dial indicator contact should sit squarely on the bore wall.)

FIGURE 31

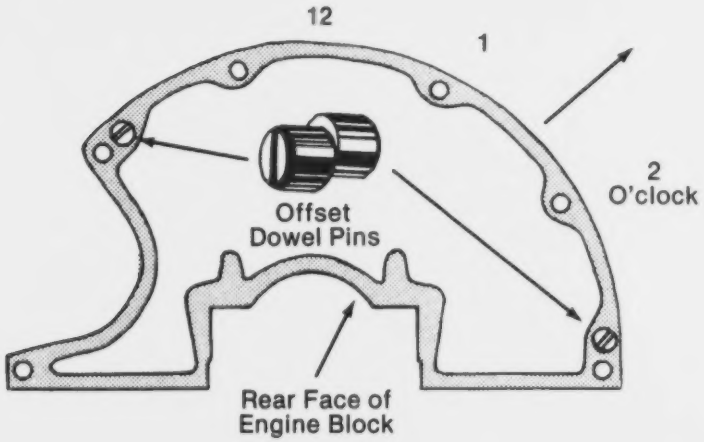


JOB SHEET #4

3. Adjust the dial to zero
4. Rotate engine clockwise
5. Record dial indicator needle deflection

(NOTE: Bore out-of-round must not exceed 0.005 inch total indicator reading. Excessive bore runout can be corrected by installing correctly sized offset dowel pins. See Figure 32.)

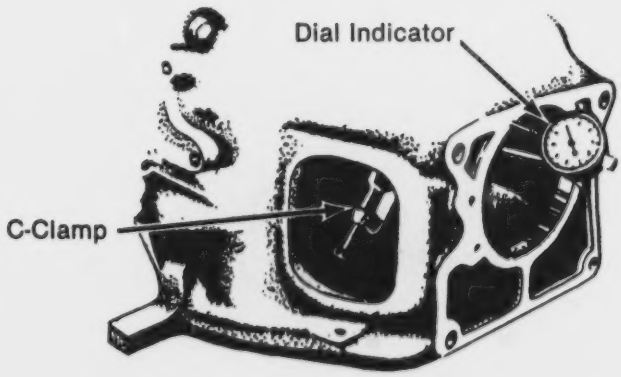
FIGURE 32



B. Check face squareness

1. Position dial indicator so that contact will ride squarely on transmission mating surface of clutch housing (Figure 33)

FIGURE 33



JOB SHEET #4

2. Adjust the dial to zero

3. Rotate engine clockwise

4. Record dial indicator reading

(NOTE: If total indicator reading is greater than 0.005 inch, the housing must be squared by placing correct thickness of shim stock between clutch housing and engine block at the point where the indicator arm is extended farthest.)

C. Clean work area; clean and put away all equipment and materials

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POWER TRAINS
UNIT I

JOB SHEET #5 — INSTALL A CLUTCH ASSEMBLY

I. Equipment and materials

A. Vehicle with clutch assembly removed

B. Clutch assembly from Job Sheet #4

C. Basic hand-tool set

D. 4 jack stands

E. Floor jack

F. Engine support stand

G. Clutch disc alignment tool

(NOTE: A clutch input shaft identical to that of the transmission may be used for clutch alignment.)

H. Safety glasses

I. Transmission jack

J. Extra drive shaft slip-joint yoke

K. Shop towels

L. Appropriate service manual

II. Procedure

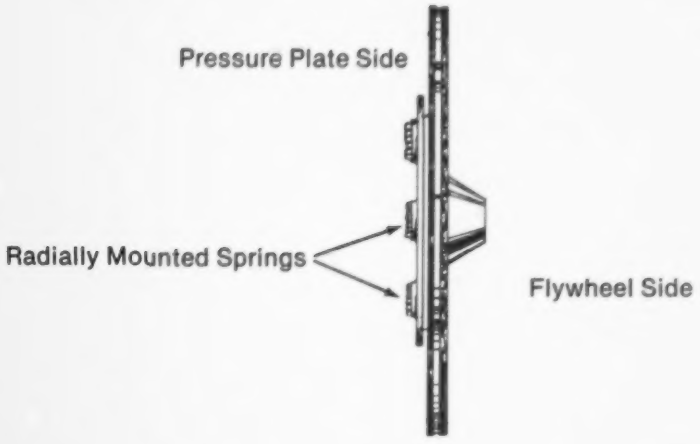
A. Clean flywheel friction surface

B. Apply small amount of wheel bearing grease to pilot bearing

JOB SHEET #5

C. Place clutch disc in mounting position, with radially mounted springs away from flywheel (Figure 34)

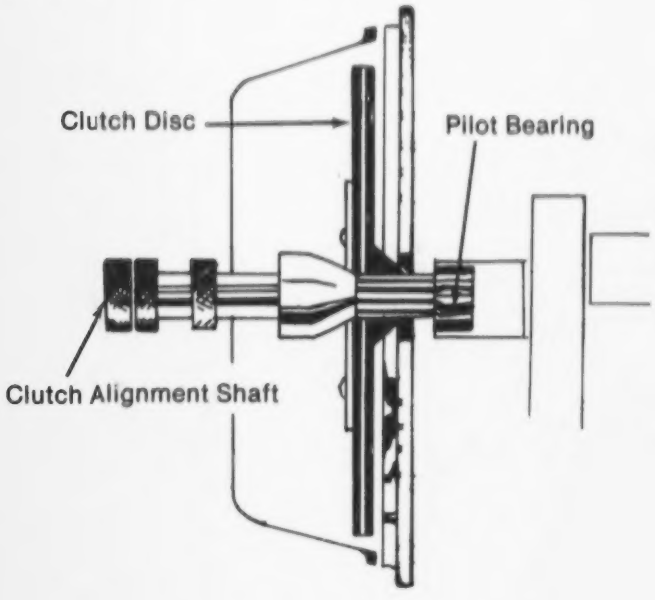
FIGURE 34



D. Position pressure plate according to balance marks

E. Install clutch alignment shaft through pressure plate and clutch disc, and extend into pilot bearing (Figure 35)

FIGURE 35



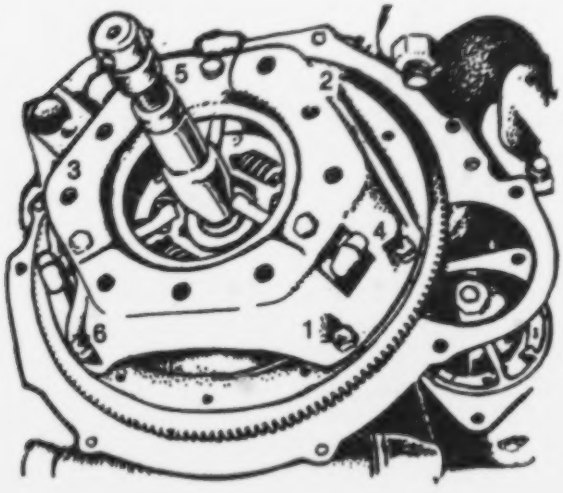
JOB SHEET #5

F. Start pressure plate attaching bolts and lock washers

(NOTE: Make sure that bolts used for the attachment of the pressure plate are the correct type. They are usually #5 shouldered bolts.)

G. To avoid distortion of pressure plate, tighten bolts in sequence (Figure 36)

FIGURE 36



Torque bolts in sequence.

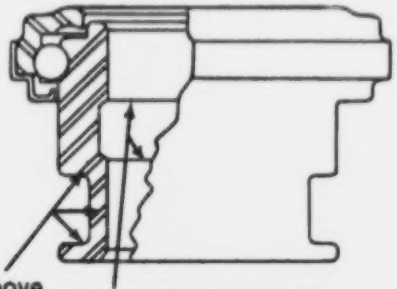
H. Torque bolts to manufacturer's specifications

I. Remove clutch alignment shaft

J. Install clutch housing and starter if applicable

K. Lubricate release bearing sleeve (Figure 37)

FIGURE 37



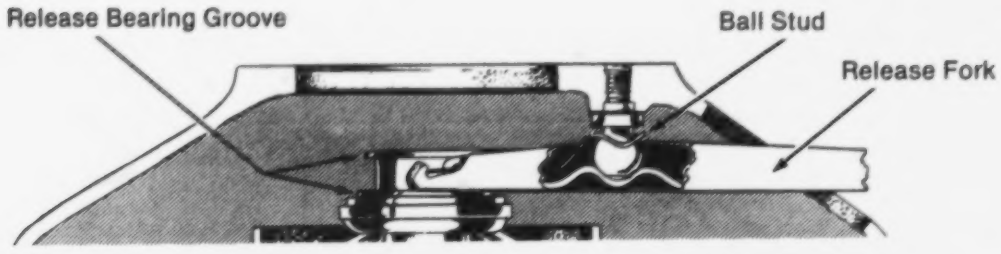
Coat this groove.

Pack this recess.

JOB SHEET #5

L. Make sure that release fork is in place (Figure 38)

FIGURE 38



M. Install release bearing

N. Connect clutch linkage

O. Install transmission

(CAUTION: Do not allow transmission weight to hang on clutch disc.)

(NOTE: Use a transmission jack and guide pins to avoid clutch disc damage during transmission installation.)

P. Attach shift linkage

Q. Install rear mount and crossmember if applicable

R. Install drive shaft, taking care to align marks

S. Check free travel on clutch pedal; adjust if necessary

(NOTE: Refer to Job Sheet #1 if necessary.)

T. Connect battery ground cable

U. Remove jack stands and lower vehicle to floor

V. Clean work area; clean and put away all tools and equipment

POWER TRAINS
UNIT I

JOB SHEET #6 — REMOVE AND REINSTALL A STANDARD TRANSMISSION

I. Equipment and materials

- A. Vehicle with standard transmission
- B. Floor jack
- C. Jack stands
- D. Basic hand-tool set
- E. Creeper
- F. Transmission jack
- G. Transmission alignment dowel pins
- H. Small hydraulic jack
- I. Suitable wood blocks, 2" × 4" × 6"
- J. Shop towels
- K. Appropriate service manual

II. Procedure

- A. Remove transmission
  1. Support vehicle on jack stands

     (NOTE: Jack stands should be placed under frame so that there is adequate working room for transmission removal.)
  2. Remove shift linkage

     (NOTE: Mark shift linkage to facilitate reassembly.)
  3. Remove any wires, linkage, or brackets attached to transmission
  4. Place reference marks on drive shaft and pinion flange to facilitate reinstallation

5. Remove drive shaft

   (NOTE: Use care to avoid dropping the U-joint roller assemblies.)

   a. Remove drive shaft attaching bolts as required

   b. Place a drive shaft yoke in rear of transmission to prevent oil from spilling during removal

   c. Support rear of engine with a small jack and wooden blocks if a rear crossmember and transmission mount are used

6. Remove crossmember bolts and rear mounting bolts

7. Remove crossmember as required

8. Remove transmission attaching bolts

9. Install transmission alignment dowel pins

10. Remove transmission

    (NOTE: Use transmission jack to aid removal.)

B. Service transmission as required

C. Reinstall transmission

1. Place transmission into clutch housing

   (NOTE: Make sure that release bearing is in place.)

2. Remove alignment dowel pins and replace transmission attaching bolts

3. Tighten transmission bolts securely; torque to manufacturer's specifications

4. Install rear crossmember and transmission mount as required

5. Remove engine support jack and wooden blocks

6. Remove drive shaft yoke used to prevent oil leakage from rear of transmission

7. Replace drive shaft, taking care to align reference marks

8. Start drive shaft attaching bolts

JOB SHEET #6

9. Tighten drive shaft bolts securely; torque to manufacturer's specifications

10. Install shift linkage

    (NOTE: Make sure that linkage does not bind and that it is properly attached.)

11. Install wires, brackets, and linkages as required

12. Fill transmission with lubricant recommended by manufacturer

13. Remove jack stands and lower vehicle to floor

D. Clean work area; clean and put away all tools and equipment

POWER TRAINS
UNIT I

JOB SHEET #7 — DISASSEMBLE, INSPECT, AND REASSEMBLE A THREE-SPEED TRANSMISSION

I. Equipment and materials

A. Vehicle with three-speed transmission

B. Basic hand-tool set

C. Brass drift punch

D. Light weight grease

E. Drain pan

F. Snap ring pliers

G. Safety glasses

H. Clean shop towels

I. Appropriate service manual

II. Procedure

(NOTE: This job sheet is written for a Saginaw three-speed fully synchronized transmission.)

A. Disassemble transmission

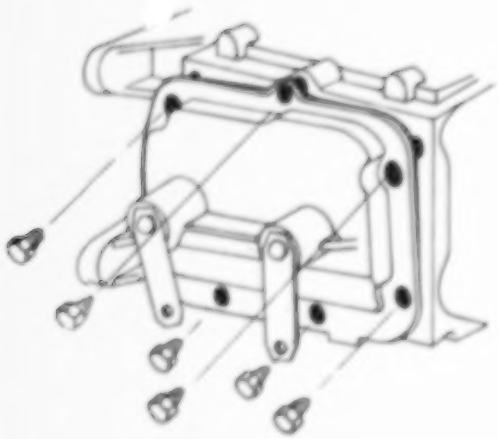
1. Drain lubricant from transmission

2. Clean outside of transmission thoroughly

3. Remove side cover attaching bolts (See Figure 39)

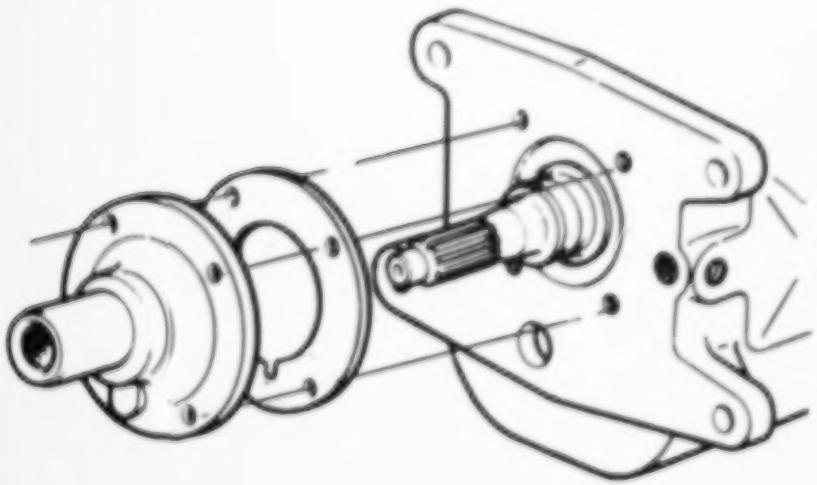
4. Remove side cover assembly (Figure 39)

FIGURE 39



5. Remove input shaft bearing retainer and gasket (Figure 40)

FIGURE 40



JOB SHEET #7

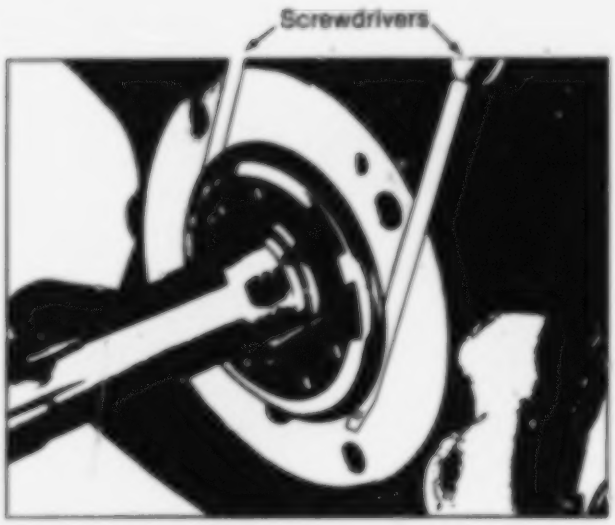
6. Remove input shaft bearing

   a. Remove snap ring from shaft

   b. Pull outward on input shaft

   c. Insert screwdrivers or suitable tools between bearing outer snap ring and case (Figure 41)

FIGURE 41



   d. While holding screwdrivers in place, remove bearing by tapping inward on input shaft with a soft hammer

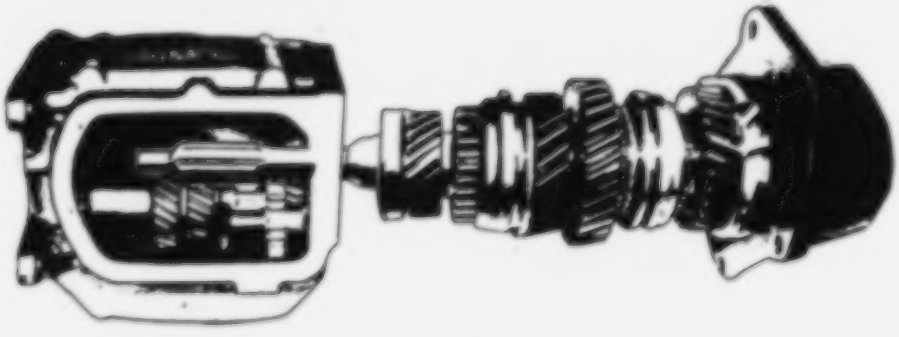
7. Remove extension housing attaching bolts

8. Remove reverse idler shaft E-ring (Figure 42)

FIGURE 42

9. Remove input shaft, output shaft, and extension housing as an assembly through rear opening of case (Figure 43)

FIGURE 43

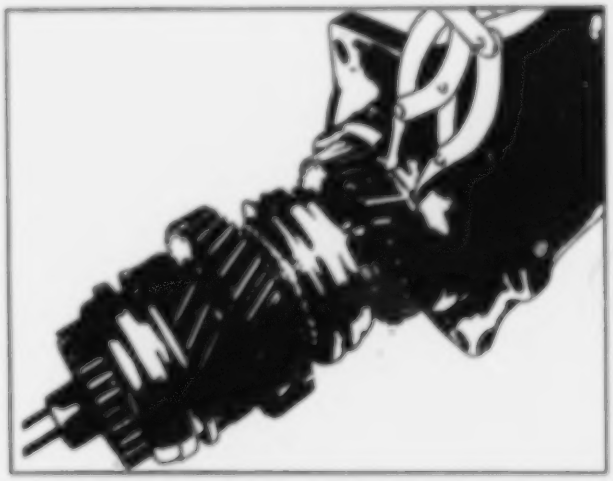


JOB SHEET #7

10. Remove input shaft, needle bearings, and synchronizer ring from output shaft

11. Expand output shaft bearing snap ring in the extension housing (Figure 44)

FIGURE 44



12. Remove bearing and shaft assembly from extension housing by tapping on splined end of shaft with a soft hammer

13. Disassemble output shaft assembly (See Figure 45)

    a. Remove snap ring retaining second and third gear synchronizer

    b. Remove synchronizer assembly

    c. Remove second gear

    d. Remove speedometer gear

    e. Remove snap ring retaining output shaft rear bearing

    f. Press rear bearing off shaft

    g. Remove reverse gear

    h. Remove snap ring retaining first and reverse synchronizer

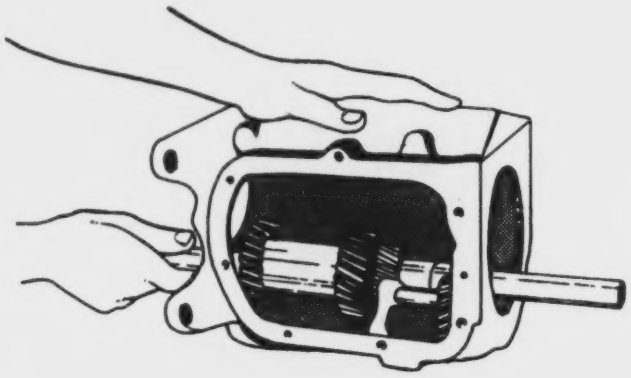
    i. Remove first and reverse synchronizer

j. Remove first gear

FIGURE 45

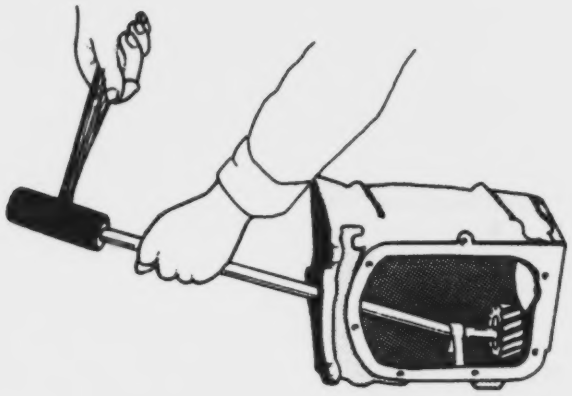
14. Remove countershaft and its Woodruff key by driving it out of the case from front to rear with a brass drift slightly smaller than the countershaft (Figure 46)

FIGURE 46



15. Remove reverse idler gear shaft by inserting long drift through front of case (Figure 47)

FIGURE 47



JOB SHEET #7

B. Clean and inspect all parts

1. Wash bearings in clean solvent
2. Blow out bearings with compressed air

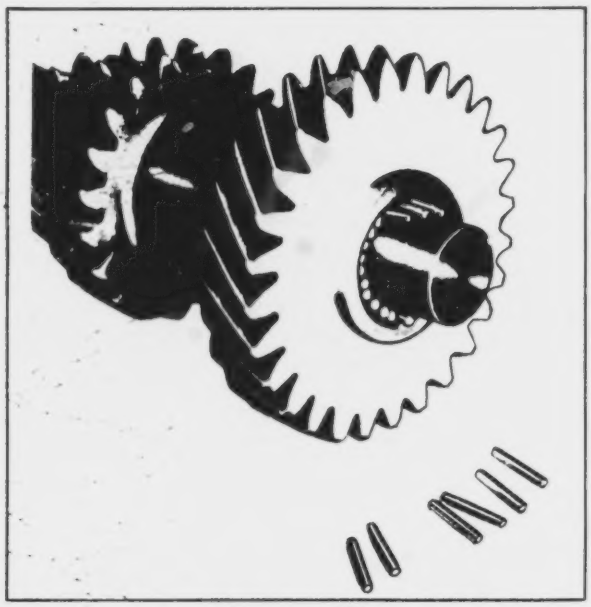
   (CAUTION: Do not let the bearings spin. Always wear safety glasses when using compressed air.)
3. Check bearings for roughness
4. Clean and inspect transmission case
5. Clean and inspect all gears for wear or damage
6. Inspect synchronizer assemblies for excessive wear
7. Replace all parts showing damage or wear

C. Reassemble transmission

1. Load a row of roller (needle) bearings and a bearing thrust washer at each end of countergear (Figure 48)

   (NOTE: The bearings can be loaded either with the aid of a loading shaft or by using grease to hold the parts in place during assembly.)

FIGURE 48



JOB SHEET #7

2. Place loaded countergear in case through rear opening

3. Install tanged thrust washers in case, with tangs toward case

4. Install countergear in case

5. Install countershaft and its Woodruff key

   (CAUTION: Be sure that countershaft picks up both thrust washers and that both tangs are aligned with their notches in the case.)

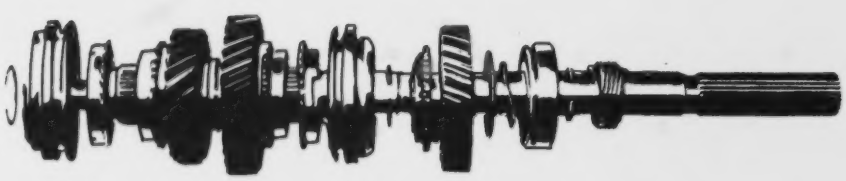
6. Install from the rear of case reverse idler gear and shaft with its Woodruff key

   (NOTE: Do not install the idler shaft E-ring at this time.)

7. Assemble output shaft

   (NOTE: Refer to Figure 49 for steps a through i.)

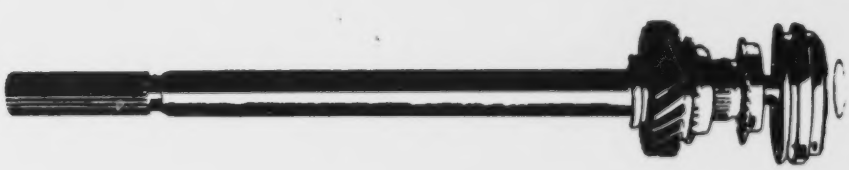
FIGURE 49



a. Turn up front end of output shaft

b. Install second speed, with clutch teeth up and rear gear face butted against output shaft flange (Figure 50)

FIGURE 50



JOB SHEET #7

c. Install a synchronizer ring (clutch teeth down) over synchronizer surface of second speed gear

d. Install second and third gear synchronizer assembly, with fork groove down

e. Press synchronizer assembly onto output shaft enough to install retaining snap ring into its groove

(CAUTION: Be sure that synchronizer ring notches align with the keys.)

f. Install snap ring

g. Turn up rear of input shaft

h. Install first gear, with clutch teeth up

(NOTE: The front face of the gear will butt against the flange of the output shaft.)

i. Install synchronizer ring (clutch teeth down) over synchronizing face of first gear

j. Install first and reverse synchronizer assembly, with fork groove down

k. Install retaining snap ring

(CAUTION: Be sure that notches of the synchronizer ring align with the keys of the synchronizer assembly.)

l. Install reverse gear, with clutch teeth down

m. Install reverse gear thrust washer (steel)

n. Install reverse gear spring washer

o. Install rear bearing, with snap ring slot down

p. Press bearing into place on output shaft

q. Install output shaft on rear bearing snap ring

8. Install output shaft assembly in extension housing

a. Place splined end of shaft through front opening in housing

b. Start rear ball bearing in its bore in the housing

c. Expand snap ring enough to allow bearing to slip through

d. Tap shaft and bearing assembly in so that snap ring will fit in its groove in the bearing outer race

JOB SHEET #7

9. Load roller bearings in main drive gear (Figure 51)

FIGURE 51

10. Install a synchronizer ring with clutch teeth over the synchronizing surface of main drive gear

11. Install main drive gear and synchronizer ring on output shaft

    (CAUTION: Be sure to align the notches in the synchronizer ring with the keys in the synchronizer assembly.)

12. Place extension housing gasket at rear of case, holding it in place with grease

13. Install into the case through the rear opening the input shaft, output shaft, and extension housing as an assembly

14. Secure extension housing to case with retaining bolts

15. Install snap ring in outer groove of input shaft bearing

16. Position bearing over stem of input shaft into front of case bore

17. Install snap ring in input shaft groove

18. Install bearing retainer and gasket on case over input shaft

    (NOTE: The retainer oil return hole should be at the bottom.)

JOB SHEET #7

19. Install reverse idler gear retainer E-ring on shaft

20. Install cover, gasket, and fork assembly on case

    (NOTE: Be sure that forks align with their synchronizer sleeve grooves.)

21. Torque all bolts to manufacturer's specifications

22. Rotate input shaft, and shift transmission to check for free rotation in all gears

D. Clean work area; clean and put away all tools and equipment

POWER TRAINS
UNIT I

JOB SHEET #8 — PERFORM A ROAD TEST FOR TRANSMISSION DIAGNOSIS

I. Equipment and materials

A. Vehicle

B. Shop towels

C. Service manual for vehicle being serviced

D. Safety glasses

II. Procedure

(NOTE: Check for proper engine performance before attempting a transmission road test.)

A. Check vehicle tire pressure and adjust as necessary

B. Check transmission fluid

1. Check for proper level at operating temperature

2. Check fluid color to determine whether it is clean and a normal red color

3. Check fluid for a burnt odor

(NOTE: Fluid discoloration or a burnt odor indicates probable internal damage to transmission.)

C. Check neutral safety switch for proper operation while starting engine

D. Start engine with gear shift selector in neutral position

E. Move gear shift selector to reverse position

1. Note the quality of shift

2. Note any noise such as a thump, grinding, or buzzing noise

(NOTE: A thump may indicate damaged motor mounts or too fast engine idle. A grinding noise may be caused by bad U-joints or damaged planetary gears. A buzzing noise could be hydraulic valve flutter, usually caused by dirty or aerated fluid.)

3. Hold brake firmly and accelerate engine moderately just long enough to confirm that transmission is not slipping

   (CAUTION: Check behind vehicle before accelerating the engine.)

F. Back up

G. Shift from reverse to drive

   1. Note time it takes for transmission to complete its shift

   2. Look for a smooth, firm shift into drive

      (NOTE: Transmission should shift quickly without excessive engine speed-up between shifts. It should not shift harshly into drive.)

H. Start off with light acceleration

   1. Note revolutions per minute at which upshifts occur

   2. Check for quality of shift

   3. Check for slow shift or engine speed-up between gears

I. Check shift in and out for smooth, firm shift

J. Stop vehicle and check for downshift that is barely noticeable

K. Return to shop and compare road test information to the diagnosis chart on the following page

L. Clean work area; clean and put away all tools and equipment

JOB SHEET #8

DIAGNOSIS CHART

PROBLEM / CAR ROAD TEST / POSSIBLE CAUSE	ALL RANGES-SLIPS	DRIVE-SLIPS-NO 1ST GEAR	LINE PRESSURE-ALL LOW	LINE PRESSURE-ALL HIGH	1-2 INTERM. CL. PRES. HIGH	1-2 INTERM. CL. PRES. LOW	2-3 DIRECT CL. PRES. HIGH	2-3 DIRECT CL. PRES. LOW	NO 1-2 UPSHIFT	1-2 U.S. EARLY/LATE	1-2 UPSHIFT @ W.O.T. ONLY	SLIPS-1-2 UPSHIFT	ROUGH-1-2 UPSHIFT	NO 2-3 UPSHIFT	2-3 U.S.-EARLY/LATE	SLIPS-2-3 UPSHIFT	ROUGH-2-3 UPSHIFT	NO WOT 1-2 UPSHIFT	NO PART TH. DOWN SHIFT	NO FULL TH. DOWN SHIFT	2-3 UPSHIFT-W.O.T. ONLY	HARSH-DOWN SHIFT	L1 RANGE-NO ENG. BRAKING	L2 RANGE-NO ENG. BRAKING	NEUTRAL-DRIVES IN NEUTRAL	REVERSE-NO REVERSE	SLIPS IN REVERSE	PARK-NO PARK-RATCHETS	NOISY-ALL RANGES	1-2 2-3 SHIFT NOISY	REV. & D. L1 & L2 NOISY	LOW COOLER-FLOW	SPEWS OIL OUT BREATHER	HUNTS BETWEEN 2 & 3 AND 3 & 2
LEGEND: X-PROBLEM AREA VS. CAUSE; *-@ "O" VACUUM ONLY; O-BALLS/#2/3/4 ONLY; L-LOCKED; S-STUCK																																	
LOW OIL LEVEL/WATER IN OIL	X	X	X			X		X				X				X									X		X	X		X	X	
VACUUM LEAK				X	X		X		X	X	X		X		X					X													
MODULATOR &/OR VALVE	X	X	*	X	X							X	X		X	X	X								X								
STRAINER &/OR GASKET	X	X	X			X		X																	X		X			X	X		
GOVERNOR-VALVE/SCREEN			X	X					X	X					X																		
VALVE BODY-GASKET/PLATE	X	X	X			X		X	X	X		X		X	X	X									X		X						
PRES. REG. &/OR BOOST VALVE	X	X	X	X	X	X	X	X	X			X	X			X	X						X	X		X	X						
BALL (#1) SHY	X	X	*			X				X		X			X	X					O			X	X								
1-2 SHIFT VALVE						X			X	X	X	X											X										
2-3 SHIFT VALVE								X					X	X	X	X		X															
MANUAL LOW CONT'L. VALVE																							X										
DETENT VALVE & LINKAGE				X						X			X						X	X	X												S
DETENT REG. VALVE																X																	
2-3 ACCUMULATOR						X					X				X																		
MANUAL VALVE/LINKAGE	X	X	X																				X	X		X	X						
POROSITY/CROSS LEAK	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X					X	X		X	X						
PUMP-GEARS	X	X	X			X		X				X				X												X					
PRIMING VALVE SHY	X	X	X																													S	
COOLER VALVE LEAK																															X	X	
CLUTCH SEAL RINGS	X	X	X			X		X	X			X		X		X							X	X		X	X						
POROUS/CROSS LEAK	X	X	X			X		X	X			X	X	X		X		X								X	X				X	X	
GASKET SCREEN-PRESSURE	X	X	X																							X	X		X		X		
BAND-INTERM. O.R.																							X										
CASE-POROUS/X LEAK	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X						X			X	X				X		
1-2 ACCUMULATOR	X	X	X			X			X			X	X																				
INTERMED. SERVO		X	X			X						X											X										
FORWARD CLUTCH ASS'Y		X																					X	X	X	L							
DIRECT CLUTCH ASS'Y								X						X		X										X	X			X			
INTERMED. CL. ASS'Y						X			X			X																		X				
L & REV. CL. ASS'Y									X			X											X			X	X						
INT. ROLLER CL. ASS'Y									X			X												X									
L. & R. ROLLER CL. ASS'Y		X																															
PARK PAWL/LINKAGE																												X					
CONVERTER ASS'Y																												X		X			
GEAR SET & BEARINGS																												X	X				

POWER TRAINS
UNIT I

JOB SHEET #9 — REPLACE AN EXTENSION HOUSING BUSHING AND SEAL

I. Equipment and materials

- A. Vehicle
- B. New extension housing bushing and seal
- C. Basic hand-tool set
- D. Seal puller
- E. Seal driver
- F. Bushing puller
- G. Bushing driver
- H. 4 jack stands
- I. Floor jack
- J. Drain pan
- K. Nonhardening sealer
- L. Shop towels

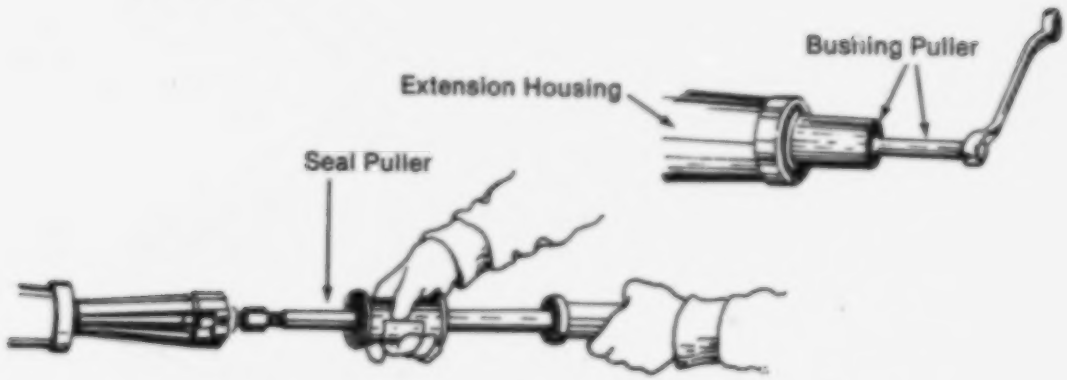
II. Procedure

- A. Raise vehicle and support securely on jack stands
- B. Mark the rear U-joint and pinion flange
- C. Position drain pan under transmission extension housing
- D. Remove drive shaft
- E. Check condition of bearing surface on slip joint
- F. Pull extension housing seal (See Figure 52)

JOB SHEET #9

G. Pull extension housing bushing (Figure 52)

FIGURE 52



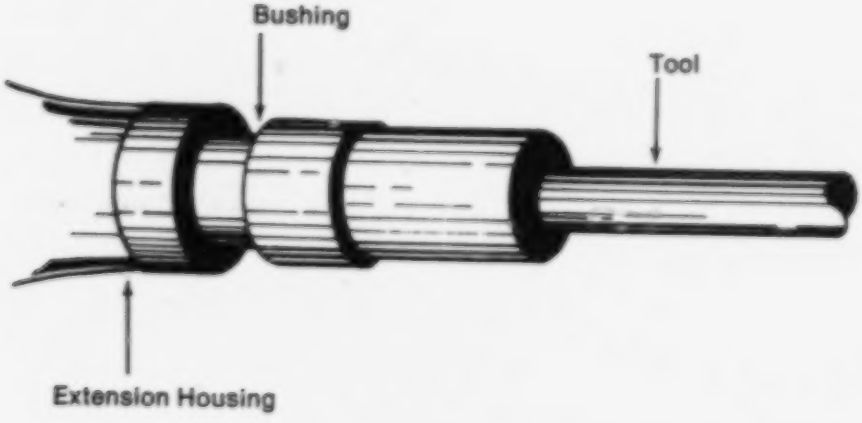
H. Clean housing seal seat and bushing area

I. Install new housing bushing, using the appropriate driver (Figure 53)

1. Place bushing on driver
2. Place bushing and driver over output shaft
3. Align assembly with housing
4. Drive bushing to proper depth

(NOTE: If the correct driver is used, the driver will bottom when the bushing is at the proper depth.)

FIGURE 53

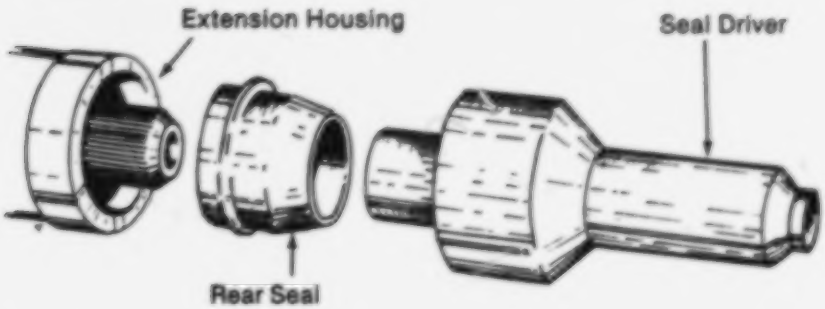


JOB SHEET #9

J. Install new seal (Figure 54)

1. Apply sealer to outside of new seal
2. Align seal on extension housing seal seat area
3. Drive seal into place with seal driver

FIGURE 54



K. Lubricate seal lip

L. Install drive shaft into transmission output shaft

M. Connect drive shaft to pinion flange, taking care to align marks previously made

N. Torque U-joint attaching bolts

O. Lower vehicle to floor

P. Start engine

Q. Check fluid level

R. Check for fluid leak at the new seal

S. Clean work area; clean and put away all tools and equipment

POWER TRAINS
UNIT I

JOB SHEET #10 — TUNE UP AN AUTOMATIC TRANSMISSION

I. Equipment and materials

A. Vehicle with automatic transmission

B. Basic hand-tool set

C. 4 jack stands

D. Floor jack

E. Large drain pan

F. Creeper

G. Safety glasses

H. Transmission fluid

I. Transmission filter package

J. New oil pan gasket

K. Transmission funnel

L. Appropriate service manual

M. Shop towels

II. Procedure

(NOTE: The exact procedure for the following tune-up activities should be followed in the service manual for the particular vehicle. Most of the procedures below are general statements; exact procedures will vary from vehicle to vehicle.)

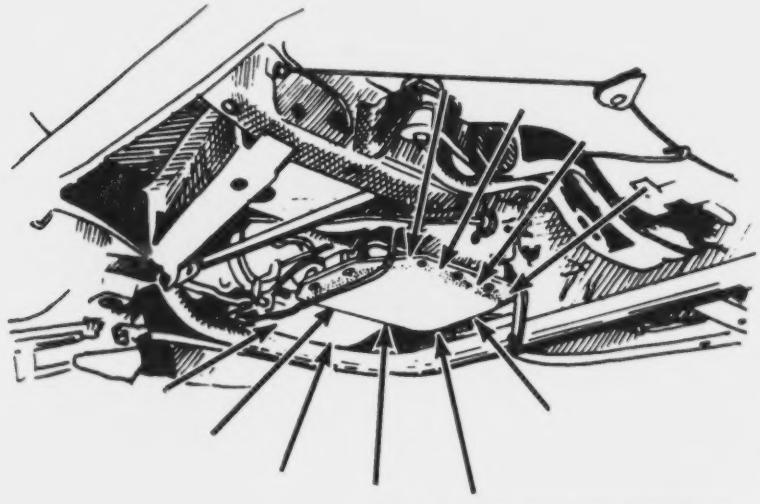
A. Road test vehicle before servicing to check for conditions that the owner may not have mentioned

B. Raise vehicle and secure on jack stands

JOB SHEET #10

C. Clean dirt and grease from around transmission oil pan and torque converter inspection cover (Figure 55)

FIGURE 55



Clean dirt at arrow locations.

D. Drain transmission fluid

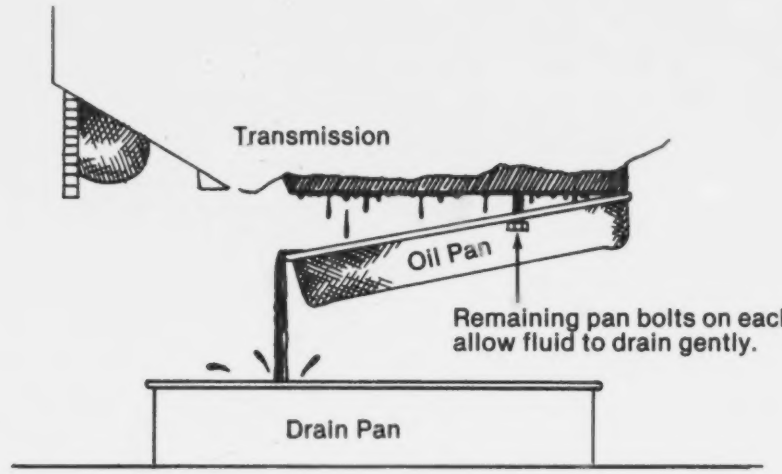
(NOTE: Follow this procedure when the oil pan does not have a drain plug.)

1. Place large drain pan under transmission oil pan
2. Remove all pan bolts except one on each side of pan (See Figure 56)
3. Loosen the two remaining bolts approximately two turns

JOB SHEET #10

4. Pry pan loose with a screwdriver to begin draining (Figure 56)

FIGURE 56



5. Hold oil pan with one hand while removing bolts with other hand
6. Pour remaining fluid gently into drain pan

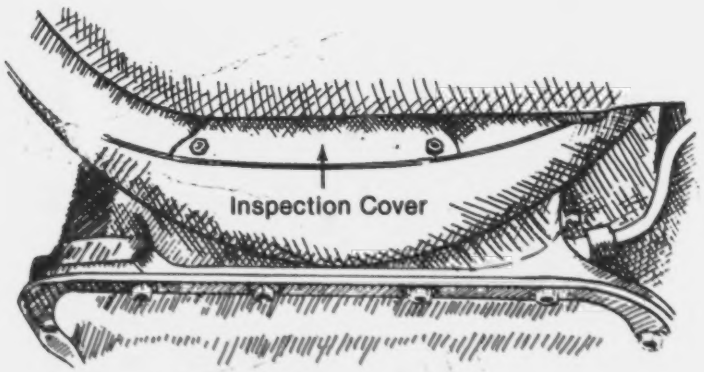
(NOTE: Check the bottom of the oil pan for metal or fiber deposits that may indicate the need for further service.)

E. Drain the torque converter

(NOTE: Some torque converters do not have drain plugs; therefore, this step may be omitted.)

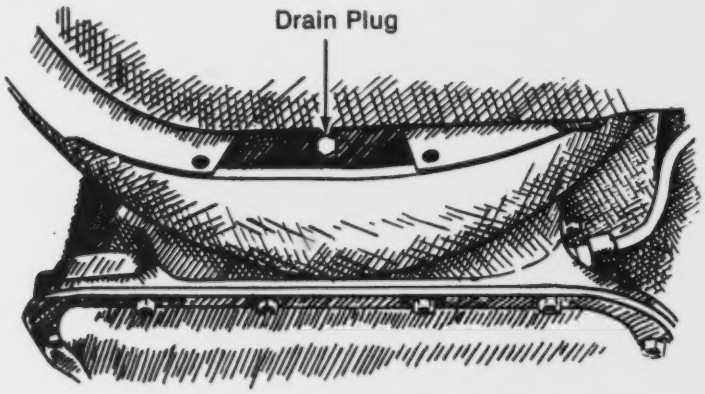
1. Remove torque converter inspection cover (Figure 57)

FIGURE 57



2. Turn engine slowly while watching for converter drain plug
3. Position drain plug at bottom (Figure 58)

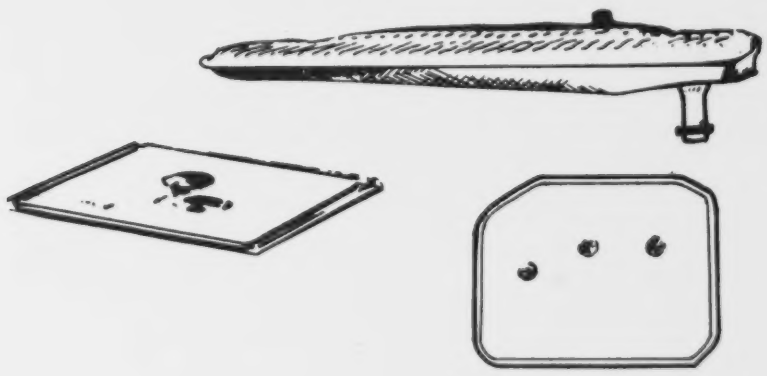
FIGURE 58



4. Place drain pan under converter plug area
5. Remove drain plug
6. Completely drain converter
7. Replace drain plug

F. Remove transmission filter element (Figure 59)

FIGURE 59



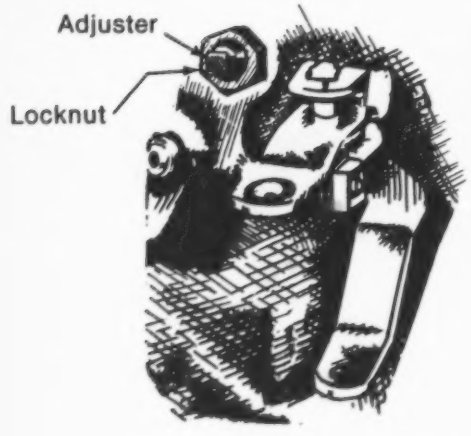
JOB SHEET #10

G. Adjust bands

(NOTE: On some transmission models, the bands are not adjustable. On other models, the adjusters may be located either inside or outside the case.)

1. Locate the band adjuster
2. Obtain correct specifications from manufacturer's service manual for each band being adjusted
3. Loosen adjuster locknut approximately five turns while holding adjuster screw (Figure 60)

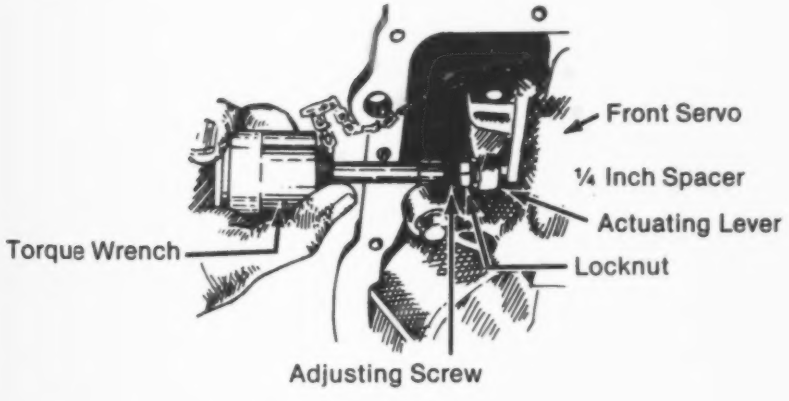
FIGURE 60



4. Tighten adjuster to specified torque

(NOTE: On some models, a spacer block should be placed between the servo piston push rod and the adjuster. See Figure 61.)

FIGURE 61



5. Back adjuster off the *exact* number of turns specified

6. Torque adjuster locknut while preventing adjuster from turning

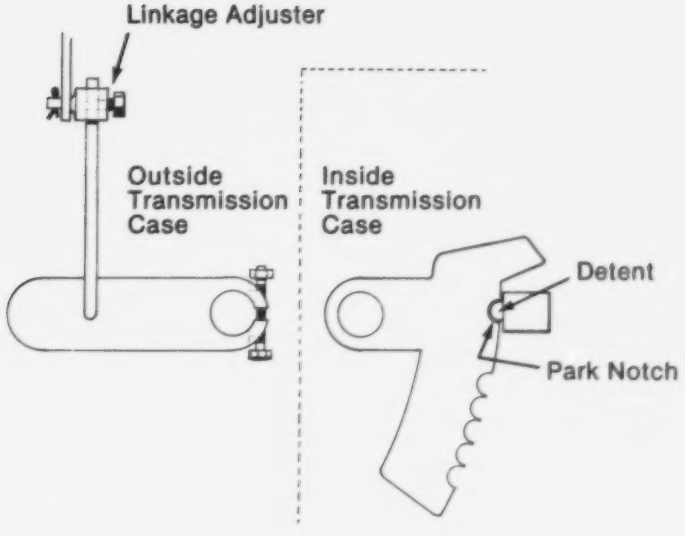
H. Adjust the shift control lever

1. Place selector lever in PARK position

2. Loosen linkage adjuster lock

3. Check to see that the shift detent on the valve body inside the transmission is sitting in the bottom of the detent notch for park (Figure 62)

FIGURE 62



4. Tighten linkage adjuster lock

JOB SHEET #10

I. Adjust neutral safety switch

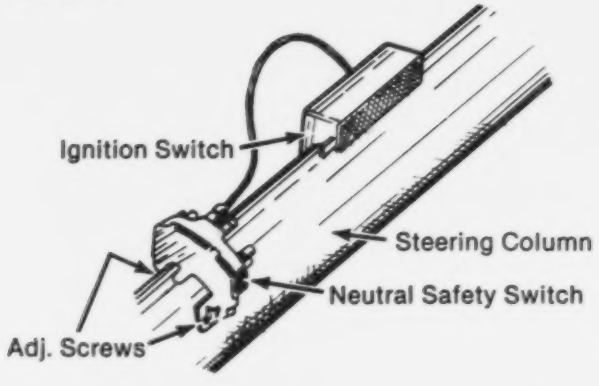
(NOTE: When adjustment is completed, the engine should crank in both PARK and NEUTRAL but not in any other position.)

1. Place shift control lever in NEUTRAL position (Figure 63)

FIGURE 63

2. Adjust neutral safety switch in either direction until correctly adjusted (Figure 64)

FIGURE 64



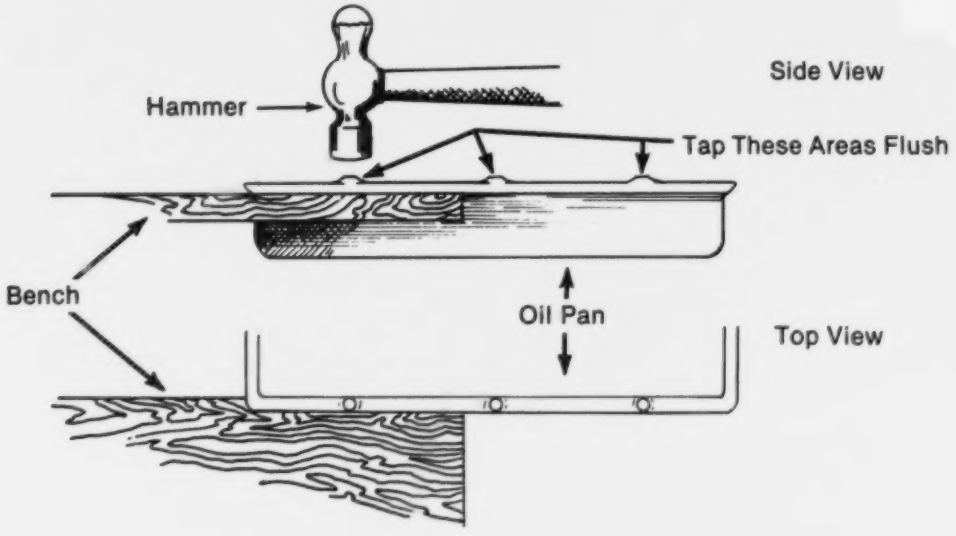
J. Install new filter element in transmission

K. Install oil pan

1. Clean old pan gasket from pan and transmission case mating surfaces

2. Straighten pan bolt hole area by laying pan rim on edge of workbench and tapping the hole area down evenly with a hammer (Figure 65)

FIGURE 65



3. Wash the pan in solvent
4. Apply a light coat of nonhardening sealer to pan mating surface
5. Place new gasket on pan mating surface
6. Attach oil pan to transmission case

   (NOTE: Start all pan bolts before tightening.)
7. Tighten all pan bolts very lightly
8. Retighten to specified torque

   (CAUTION: Use care not to mash gasket while tightening pan bolts.)

L. Lower vehicle, maintaining rear wheel approximately 4 inches off floor

M. Adjust throttle linkage if vehicle is so equipped

(NOTE: Refer to the appropriate service manual for proper adjustment procedures.)

JOB SHEET #10

N. Fill transmission with fluid

(NOTE: Refer to manufacturer's specifications for fluid type and transmission capacity.)

1. Pour 4 quarts of fluid into transmission filler tube
2. Start engine and place shift lever in NEUTRAL position

   (NOTE: On vehicles with the torque converter drained, 3 to 4 more quarts of fluid may have to be added. On vehicles without a torque converter drain, the fluid level should be close to full.)
3. Add fluid until it is to the ADD line on dipstick
4. Operate engine approximately fifteen minutes until transmission fluid is at operating temperature
5. Add fluid to the FULL mark on dipstick

   (CAUTION: Do not overfill the transmission. It is usually better to be slightly below the FULL mark than to be over the mark.)

O. Turn off engine

P. Lower rear wheels to floor

Q. Road test vehicle for proper operation

R. Check for fluid leaks

S. Clean work area; clean and put away all tools and equipment

POWER TRAINS
UNIT I

JOB SHEET #11 — REMOVE AND REINSTALL A DRIVE (PROPELLER) SHAFT

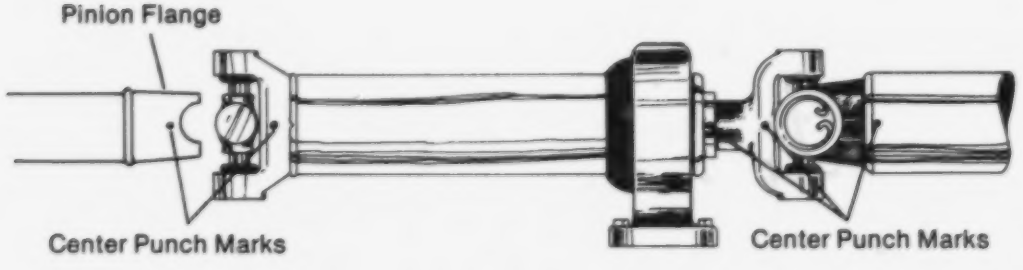
I. Equipment and materials

- A. Vehicle
- B. Floor jack
- C. Jack stands
- D. Basic hand-tool set
- E. Soft hammer
- F. Torque wrench and adapter
- G. Creeper
- H. Safety glasses
- I. Appropriate service manual
- J. Shop towels
- K. Masking tape

II. Procedure

- A. Jack up rear of vehicle and place jack stands under frame
- B. Mark all joints and yokes with a center punch to retain balance and phasing (Figure 66)

FIGURE 66



C. Remove drive shaft attaching bolts

(NOTE: Study the drive shaft to determine how it is fastened.)

D. Remove the center support bearing if a two-piece drive shaft is used

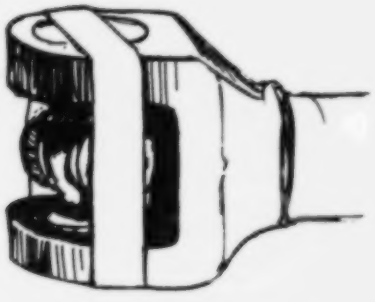
(NOTE: Check between center support and frame for shims. If shims are used, they must be replaced when propeller shaft is reinstalled.)

E. Remove drive shaft from vehicle

(CAUTION: When removing, replacing, or servicing a drive shaft, careless handling can damage the shaft and U-joints.)

1. Tape U-joint rollers to prevent loss of needle bearings (Figure 67)

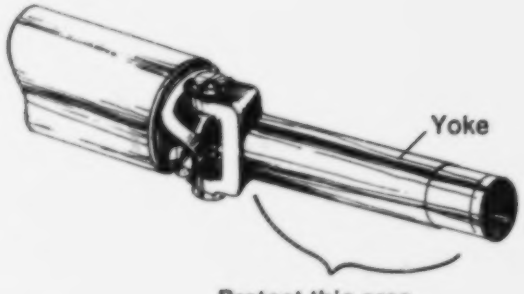
FIGURE 67



Tape rollers on.

2. Protect slip yoke to prevent damage during removal (Figure 68)

FIGURE 68



Protect this area.

JOB SHEET #11

F. Service drive shaft

G. Reinstall drive shaft

1. Place in position and check alignment marks

   (NOTE: All mounting surfaces should be clean and free of nicks before assembly.)

2. Position all fasteners correctly, and tighten evenly

3. Replace fasteners, if used, in center support bearing

   (NOTE: Replace shims, if used, between frame and support.)

4. Torque all fasteners to manufacturer's specifications

H. Jack up rear of vehicle and remove jack stands

I. Lower vehicle to floor

J. Clean work area; clean and put away all tools and equipment

POWER TRAINS
UNIT I

JOB SHEET #12 — REMOVE AND REINSTALL A CROSS-AND-ROLLER U-JOINT

I. Equipment and materials

A. Drive shaft with cross-and-roller U-joint

B. Basic hand-tool set

C. Soft hammer

D. Brass punch

E. Vise

F. Safety glasses

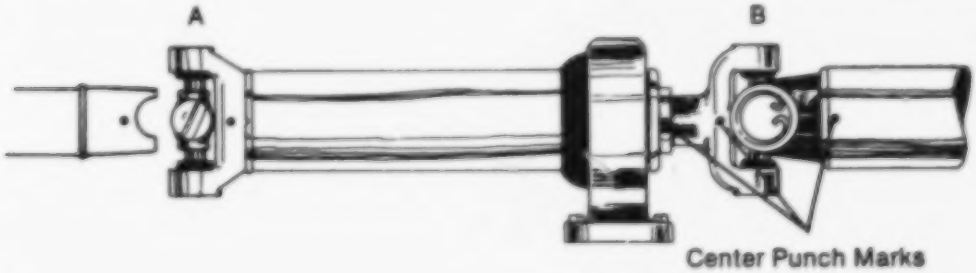
G. Shop towels

II. Procedure

A. Mark all parts with a center punch so that parts may be reassembled in same positions (Figure 69)

(NOTE: It is very important to align drive shaft parts A and B when reassembling the shaft.)

FIGURE 69



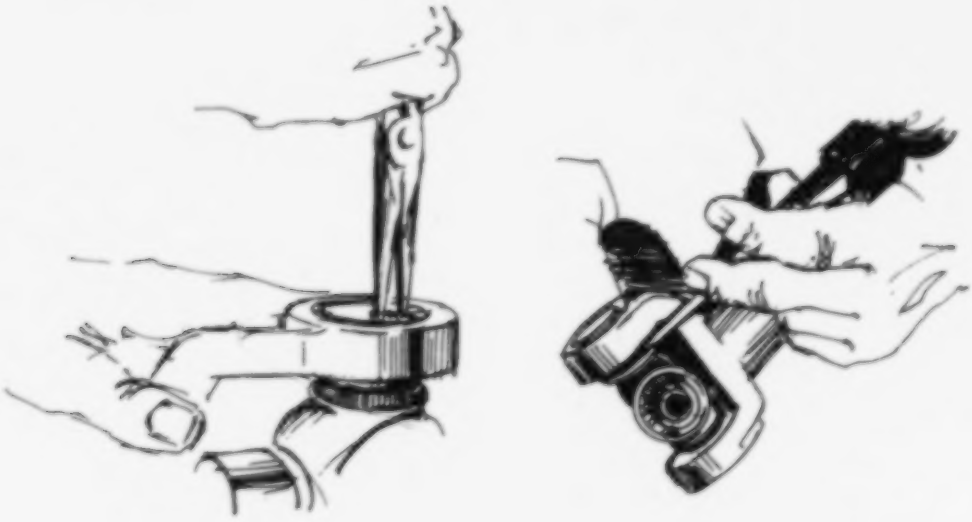
Center Punch Marks

JOB SHEET #12

B. Remove snap rings or retainer plates and grease fittings as required (Figure 70)

(CAUTION: If the drive shaft is held in the vise while removing the snap rings, do not bend, overtighten, or scar the shaft with the vise.)

FIGURE 70

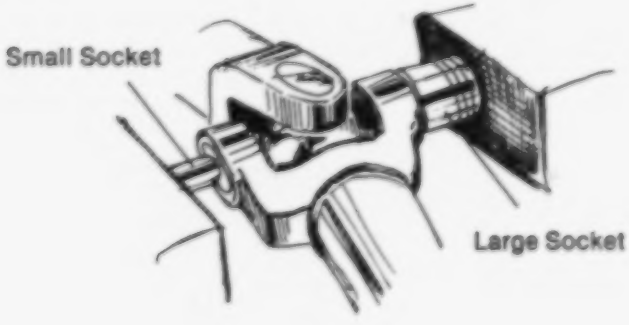


C. Place a small socket against one roller; place a large socket against yoke on opposite side (See Figure 71)

D. Place in a vise and close vise jaws until roller assembly is pressed out of yoke (Figure 71)

(CAUTION: Be sure that the large socket has enough room to allow the roller to enter without wedging in the socket.)

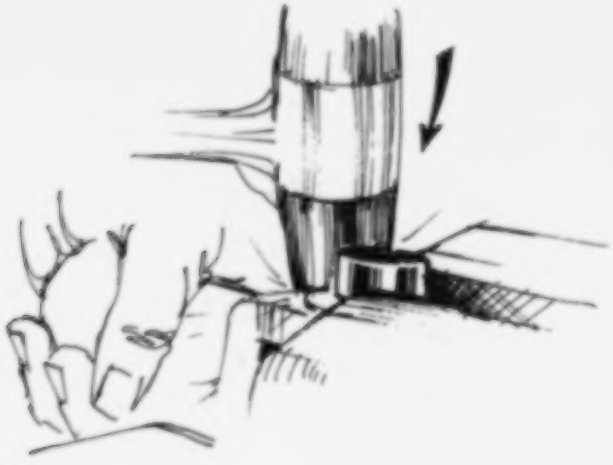
FIGURE 71



JOB SHEET #12

(NOTE: Remove roller with pliers or soft hammer. See Figure 72.)

FIGURE 72



E. Place small socket on remaining roller; place large socket against yoke on opposite side

(CAUTION: Use caution to avoid damaging seal shields.)

F. Place in a vise and close vise jaws until roller assembly is pressed out of yoke

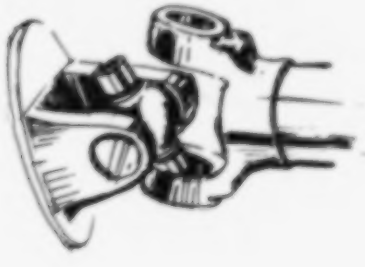
(NOTE: Refer to Figure 71.)

G. Remove roller with pliers or soft hammer

(NOTE: Refer to Figure 72.)

H. Tip cross and remove from yoke (Figure 73)

FIGURE 73



JOB SHEET #12

I. Remove other rollers using same procedure

J. Inspect cross trunnions for excessive wear, corrosion, or grooving; check all needle bearings for chipping or breakage

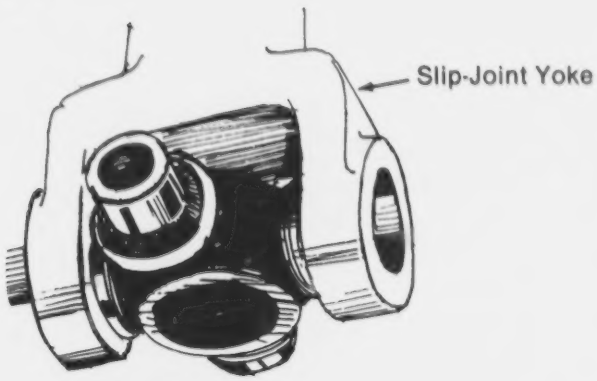
(NOTE: If the components are not worn, they may be correctly lubricated and reused. If there is any sign of wear, install a new U-joint.)

K. Reassemble U-joint

1. Place cross in drive shaft yoke (Figure 74)

(NOTE: On U-joint with grease fittings, the fitting should be positioned on the drive shaft side to allow clearance for lubrication after installation.)

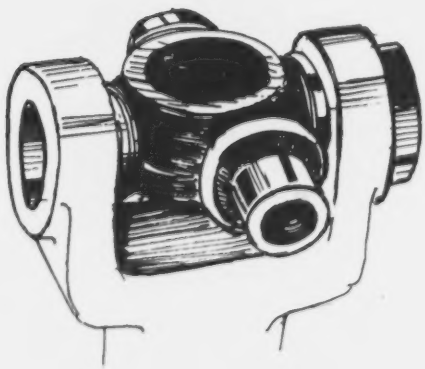
FIGURE 74



2. Slide cross to one side and start a roller over cross bearing race (See Figure 75)

3. Start roller in yoke eye (Figure 75)

FIGURE 75

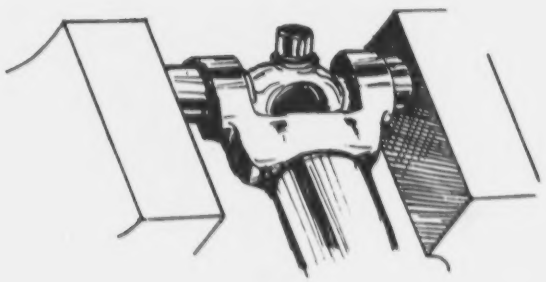


JOB SHEET #12

4. Place U-joint in vise and press roller into yoke eye (Figure 76)

   (NOTE: Be sure to keep the cross in the roller bearings to prevent the bearings from loosening or moving from their proper position.)

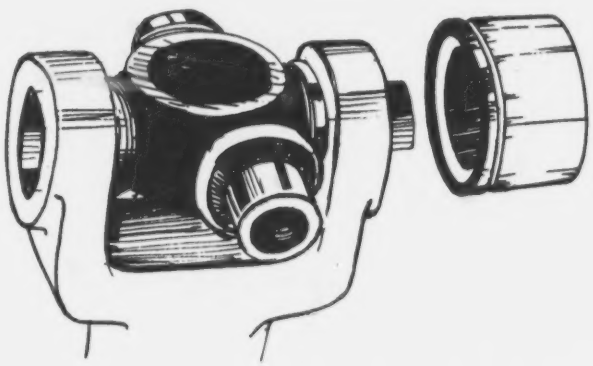
FIGURE 76



5. Install snap ring into roller groove or yoke eye groove according to type of U-joint

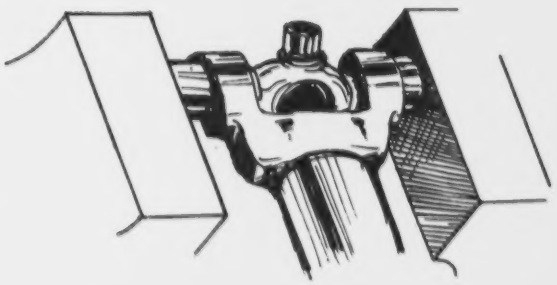
6. Slide cross slightly out of roller so that opposite roller can be started on cross bearing race (Figure 77)

FIGURE 77



7. Place in vise and press roller into yoke eye sufficiently to install snap ring (Figure 78)

FIGURE 78

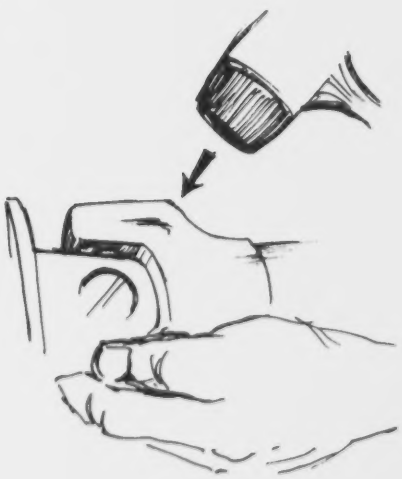


8. Install remaining U-joint rollers using the same procedure; install remaining snap rings

9. Strike yoke to seat rollers against snap rings and to position the cross (Figure 79)

   (NOTE: Make sure that U-joint does not bind throughout its range of movement.)

FIGURE 79



L. Clean work area; clean and put away all tools and equipment

POWER TRAINS
UNIT I

JOB SHEET #13 — REMOVE AND REINSTALL A BALL-AND-TRUNNION U-JOINT

I. Equipment and materials

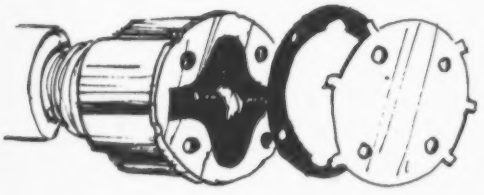
- A. Drive shaft with ball-and-trunnion U-joint
- B. Safety glasses
- C. Basic hand-tool set
- D. Arbor press and vise
- E. Steel rule
- F. Shop towels

II. Procedure

- A. Secure drive shaft in vise

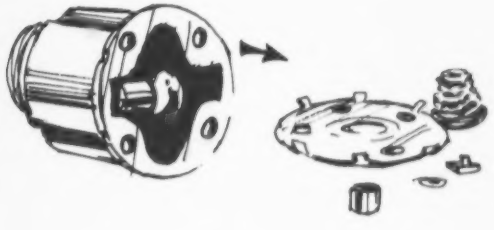
  (NOTE: Clamp drive shaft in the vise carefully to avoid damage to shaft.)
- B. Straighten the tabs that fasten the sheet metal cover to U-joint housing
- C. Remove sheet metal cover and gasket (Figure 80)

FIGURE 80



- D. Push U-joint housing back to expose the trunnion pin; remove thrust button, spring, ball, rollers, and thrust washer from each end of pin (Figure 81)

FIGURE 81



JOB SHEET #13

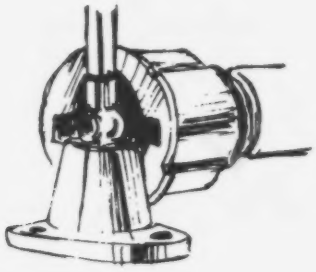
E. Remove clamps and loosen rubber dust cover

F. Clean and examine trunnion pin and raceways in U-joint housing

(NOTE: If the components are not worn, they can be lubricated and reused. If they show any signs of wear, they should be replaced.)

G. Press out trunnion pin if replacement is necessary (Figure 82)

FIGURE 82



H. Remove U-joint housing

I. Remove rubber dust cover

J. Reassemble U-joint

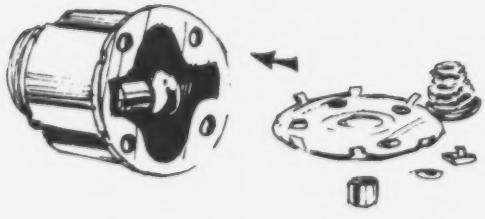
1. Place rubber dust cover, clamps, and U-joint housing on propeller shaft

2. Start and press trunnion pin through end of drive shaft

(NOTE: Make sure that trunnion pin is exactly centered.)

3. Install thrust washers, balls, rollers, spring, and thrust buttons on each end of trunnion pin (Figure 83)

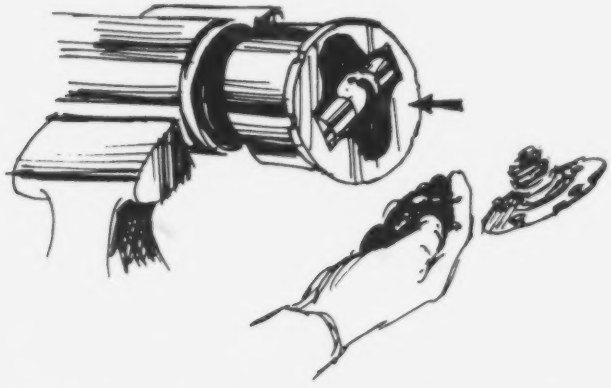
FIGURE 83



JOB SHEET #13

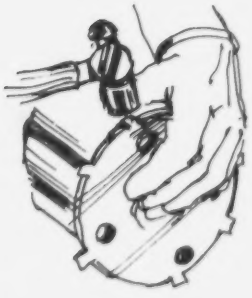
4. Position U-joint housing over trunnion pin assembly
5. Position rubber dust cover and tighten clamps
6. Lubricate balls, rollers, and raceways (Figure 84)

FIGURE 84



7. Install sheet metal cover and gasket on drive shaft housing, and bend holding tabs (Figure 85)

FIGURE 85



K. Clean work area; clean and put away all tools and equipment

POWER TRAINS
UNIT I

JOB SHEET #14 — BALANCE A DRIVE (PROPELLER) SHAFT

I. Equipment and materials

A. Vehicle

B. Hose clamps (slightly larger than propeller shaft)

C. Chalk, crayon, or pencil

D. 5 jack stands

E. Floor jack

(NOTE: Use a twin-post hoist if available.)

F. Basic hand-tool set

G. Safety glasses

II. Procedure

(NOTE: If a balance problem exists, the drive shaft should be cleaned of built-up foreign materials and checked to determine whether any balance weights have been lost and whether shaft has been properly installed. Road test after cleaning. If the problem still exists, disconnect the drive shaft from the pinion and rotate 180 degrees. Reconnect drive shaft, and road test again. If the problem still exists, balance the drive shaft using the following procedure.)

A. Raise vehicle on jack; place jack stands so that rear of vehicle is supported on rear axle housing with wheels free to rotate

B. Set a jack stand approximately 1 inch from drive shaft (See Figure 86)

C. Start engine and rotate drive shaft at 2,000 to 2,500 rpm

JOB SHEET #14

D. Mark drive shaft by carefully bringing crayon or pencil up until it just barely contacts rear of spinning drive shaft (Figure 86)

(NOTE: The mark made by the crayon or pencil will indicate the heavy side of the shaft.)

(CAUTION: Avoid contact with the spinning shaft and tires. While marking the shaft, avoid areas where balance weights are located; they could injure your hands.)

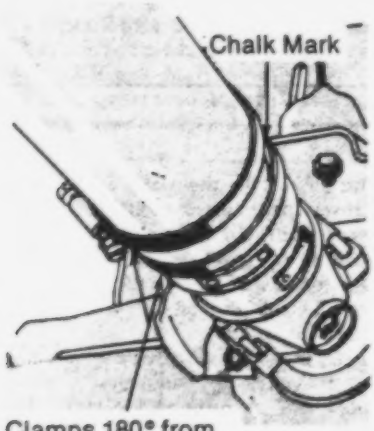
FIGURE 86

E. Turn off engine

JOB SHEET #14

F. Install two screw-type hose clamps on rear of drive shaft so that screw heads are 180 degrees from mark on drive shaft (Figure 87)

FIGURE 87



Clamps 180° from Chalk Mark

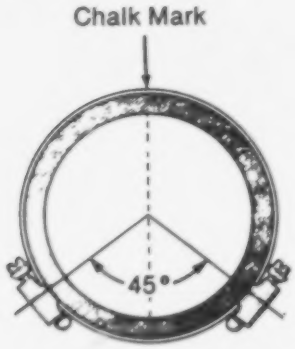
G. Tighten clamps securely

H. Run vehicle up to 3,500 rpm

(NOTE: If no vibration is felt, road test the vehicle as a final test. If vibration still exists, proceed as follows.)

I. Rotate clamp heads approximately 45 degrees from each other and retest (Figure 88)

FIGURE 88



JOB SHEET #14

J. Continue to rotate clamp heads apart in smaller amounts until vibration is eliminated

K. Clean work area; clean and put away all tools and materials

POWER TRAINS
UNIT I

JOB SHEET #15 — CHECK AND ADJUST U-JOINT ANGLES

I. Equipment and materials

A. Vehicle

B. Basic hand-tool set

C. Safety glasses

D. Inclinometer (angle gauge)

E. Jack stands or hoist

F. Floor jack

G. Assortment of shims

H. Transmission jack

I. Appropriate service manual

J. Shop towels

II. Procedure

A. Raise vehicle and support on jack stands or hoist so that vehicle is supported on rear axle housing in normal operating position

(NOTE: Specifications are usually listed for an approximately level empty vehicle with a full gas tank.)

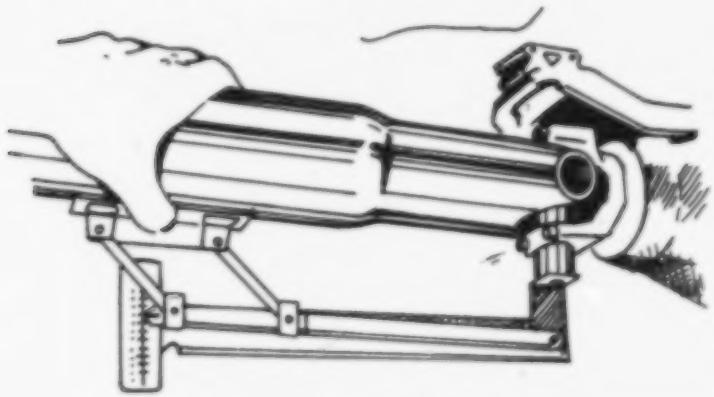
B. Mount inclinometer at rear U-joint according to manufacturer's directions

(NOTE: The figures shown are of one particular gauge; applications will vary from gauge to gauge.)

C. Take U-joint angle reading (Figure 89)

(NOTE: Make sure that the gauge is set on clean areas of the shaft. Calibration of the inclinometer can be performed by attaching to any level surface and adjusting the gauge to zero.)

FIGURE 89



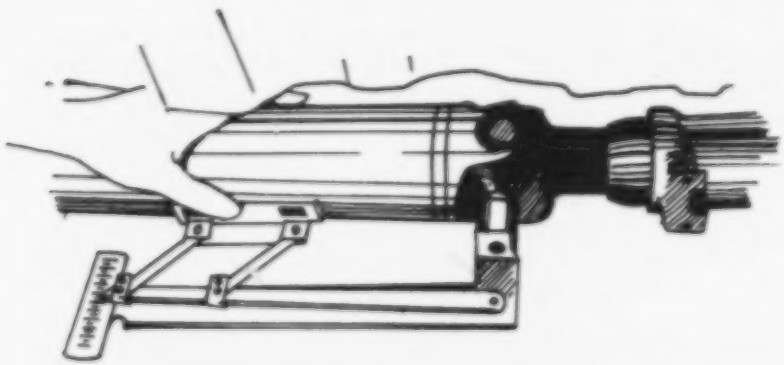
Measuring U-Joint Angle at Axle

D. Compare gauge reading to specifications to determine amount of correction needed

E. Mount inclinometer at front of propeller shaft and front U-joint (See Figure 90)

F. Take U-joint angle reading (Figure 90)

FIGURE 90



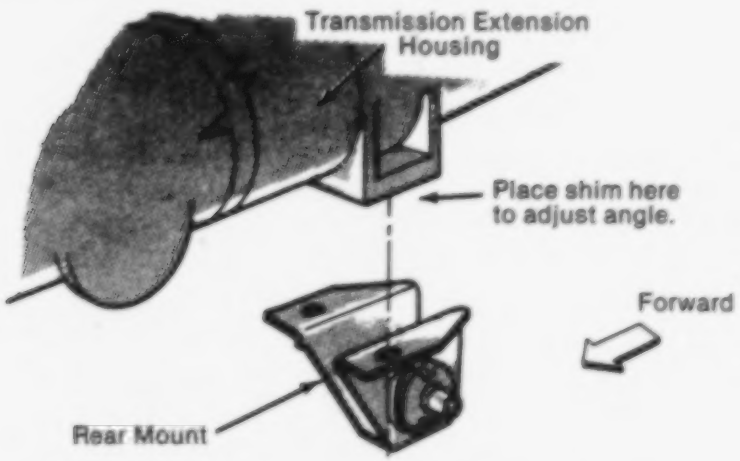
Measuring U-Joint Angle at Transmission

JOB SHEET #15

G. Correct front U-joint angle

(NOTE: For two-piece drive shafts, adjusting the shim pack at the center support bearing will change both front and rear angles. If angle reads low or negative, no correction is required. To reduce large angles, place shims between extension housing and engine rear mount. See Figure 91.)

FIGURE 91



1. Remove engine rear mount bolts at extension housing
2. Raise transmission with transmission jack enough to install shims

   (NOTE: Usually a 1/8-inch shim will reduce the angle approximately 1/4 degree.)
3. Install correct number of shims
4. Lower transmission
5. Install bolts; tighten to specified torque
6. Remeasure angle to check results of the adjustment

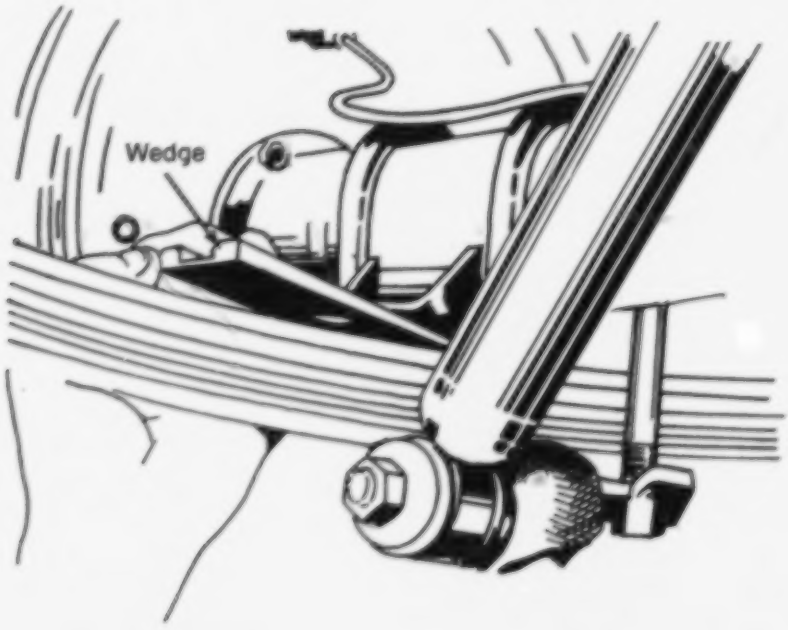
H. Correct rear U-joint angle

(NOTE: If correction is necessary, tapered wedge-type shims in values of 1 to 4 degrees are available for the rear axle with leaf-type springs. On trailing arm suspension, shims will be used between the upper control arm and frame.)

JOB SHEET #15

1. Loosen spring U-bolt nuts enough to install shims between spring and spring seat (Figure 92)

FIGURE 92



2. Install shims

   (NOTE: Installing the thick end of shims toward the front of the vehicle reduces the angle. Installing the thick end toward the rear of the vehicle increases the angle.)

3. Tighten U-bolt nuts to proper torque

4. Remeasure U-joint angle to check results of adjustment

   (NOTE: Do not shim more than 1/4 inch measured at the center of the shim. If more correction is indicated, look for possible broken spring, mislocated spring seat, or other suspension wear or damage.)

I. Remove jack stands and lower vehicle to floor

J. Clean work area; clean and put away all tools and equipment

POWER TRAINS
UNIT I

JOB SHEET #16 — MEASURE BACKLASH BETWEEN RING GEAR AND DRIVE PINION

I. Equipment and materials

A. Carrier assembly, removed from vehicle

B. Universal dial-indicator set

C. Torque wrench

D. Basic hand-tool set

E. Bench vise

F. Appropriate service manual

G. Shop towels

II. Procedure

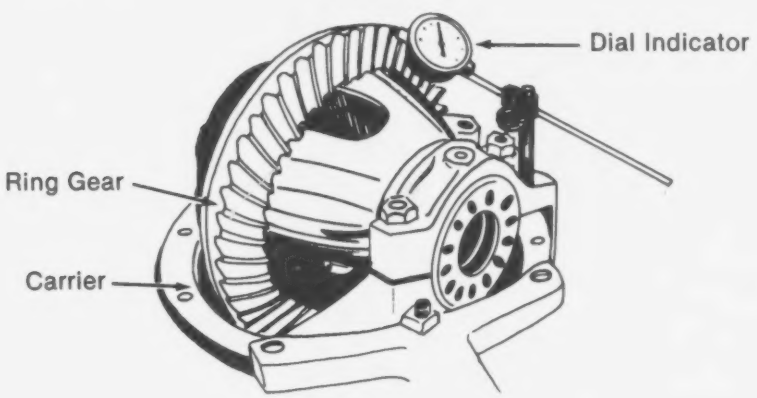
A. Secure carrier housing in bench vise or suitable holding fixture

B. Clean all lubricant and any other contamination from assembly, particularly the gear teeth; air dry

(NOTE: Bearing retainer caps should be at specified torque, and drive pinion preload should be correct.)

C. Attach dial indicator clamp to carrier housing (Figure 93)

FIGURE 93



JOB SHEET #16

D. Attach dial indicator and required linkage so that indicator stem is set at a 90-degree angle to ring gear tooth face (See Figure 93)

E. Hold drive pinion flange stationary during the test

F. Rotate ring gear in each direction through the slack between gear teeth

(NOTE: This is the backlash.)

G. Set dial indicator to zero, with ring gear at end of slack to measure backlash

H. Rotate ring gear back through the slack

I. Read indicator

(NOTE: The reading will indicate the amount of backlash in thousandths of an inch.)

J. Compare your reading with manufacturer's specifications, generally 0.005 inch to 0.008 inch

K. Measure backlash at four positions on the ring gear at approximately 90-degree intervals to obtain an average backlash reading

L. Clean work area; clean and put away all tools and equipment

POWER TRAINS
UNIT I

JOB SHEET #17 — TEST RING GEAR AND DRIVE PINION GEAR TOOTH CONTACT PATTERN

I. Equipment and materials

A. Carrier assembly, removed from vehicle

B. Pattern paste (mixture of motor oil and red lead, white lead, or Prussian blue)

C. Basic hand-tool set

D. Pinch bar

E. Small brush with stiff bristles

F. Bench vise

G. Shop towels

II. Procedure

A. Prepare pattern paste as required

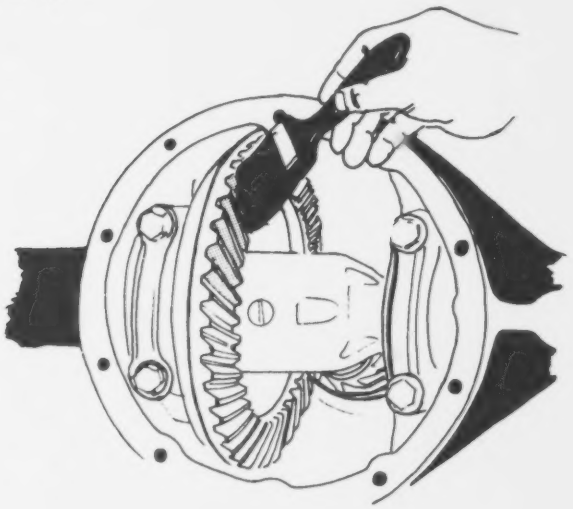
B. Secure carrier assembly housing in bench vise or suitable fixture

C. Clean and air dry drive pinion and ring gear teeth

D. Apply pattern paste to both sides of ring gear teeth (Figure 94)

(NOTE: Apply the paste only on four groups of four teeth each. The groups should be 90 degrees apart on the ring gear.)

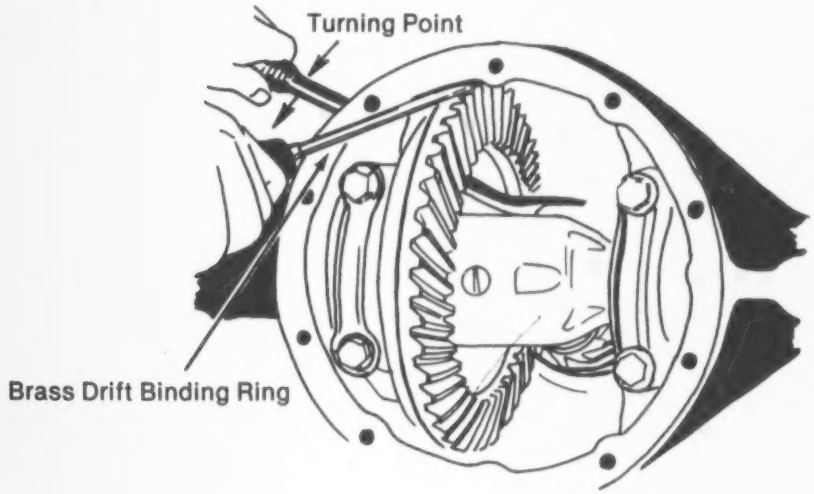
FIGURE 94



JOB SHEET #17

E. Turn drive pinion while holding on to ring gear, so that one group of coated teeth passes back and forth across pinion gear until a readable impression is produced on both sides of ring gear teeth (Figure 95)

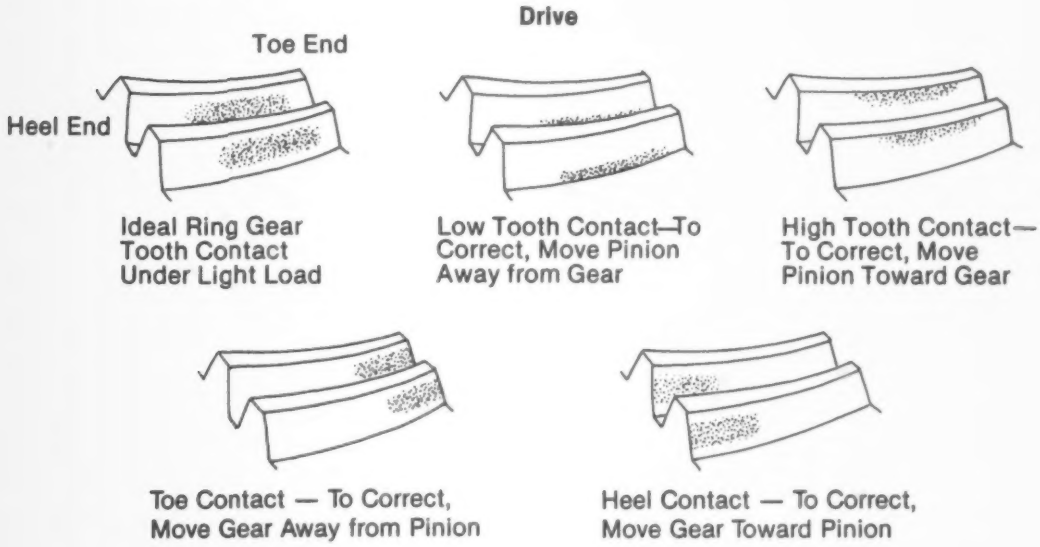
FIGURE 95



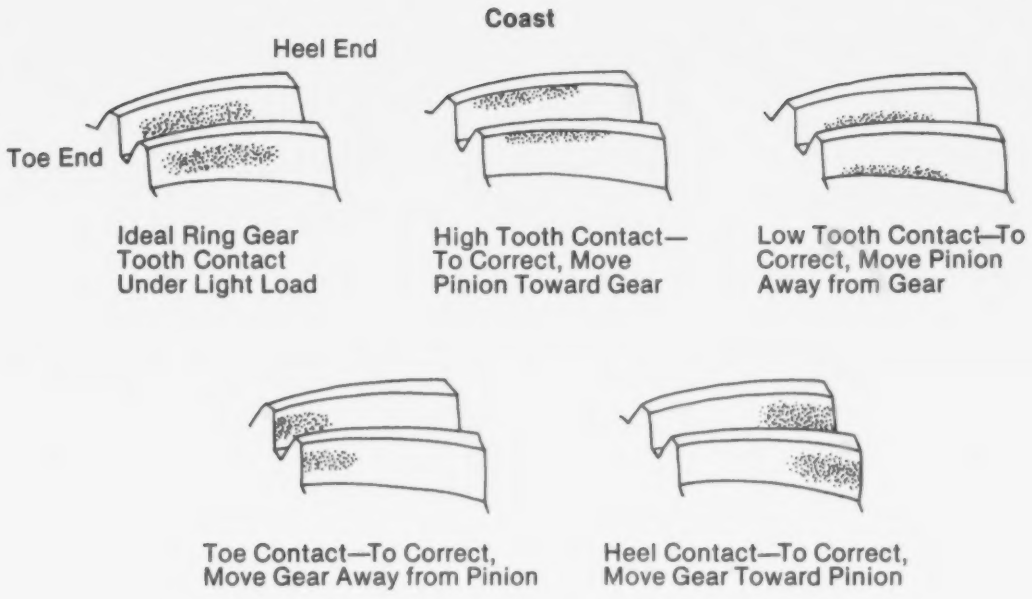
F. Compare ring gear tooth pattern with patterns in Figure 96

(NOTE: The caption under each pattern indicates the necessary corrective adjustments.)

FIGURE 96


Drive
Toe End
Heel End
Ideal Ring Gear Tooth Contact Under Light Load
Low Tooth Contact—To Correct, Move Pinion Away from Gear
High Tooth Contact—To Correct, Move Pinion Toward Gear
Toe Contact — To Correct, Move Gear Away from Pinion
Heel Contact — To Correct, Move Gear Toward Pinion

JOB SHEET #17


Coast
Heel End
Toe End
Ideal Ring Gear Tooth Contact Under Light Load
High Tooth Contact—To Correct, Move Pinion Toward Gear
Low Tooth Contact—To Correct, Move Pinion Away from Gear
Toe Contact—To Correct, Move Gear Away from Pinion
Heel Contact—To Correct, Move Gear Toward Pinion

G. Make contact patterns on remaining three groups of teeth

H. Compare patterns from all four groups of teeth to develop an average pattern

(NOTE: The four patterns should be identical; if they are *not*, the ring gear has too much runout.)

I. Clean work area; clean and put away all tools and equipment

POWER TRAINS
UNIT I

JOB SHEET #18 — INSTALL A DRIVE PINION SEAL

I. Equipment and materials

- A. Vehicle
- B. New drive pinion seal
- C. New collapsible spacer
- D. Floor jack and jack stands
- E. Safety glasses
- F. Foot-pound torque wrench, 0 to 250 pound range
- G. Inch-pound torque wrench
- H. Basic hand-tool set
- I. Flange holding tool
- J. Seal puller
- K. Seal driver
- L. Hammer
- M. Drain pan
- N. Gear lubricant
- O. Shop towels
- P. Nonhardening sealer
- Q. Appropriate service manual

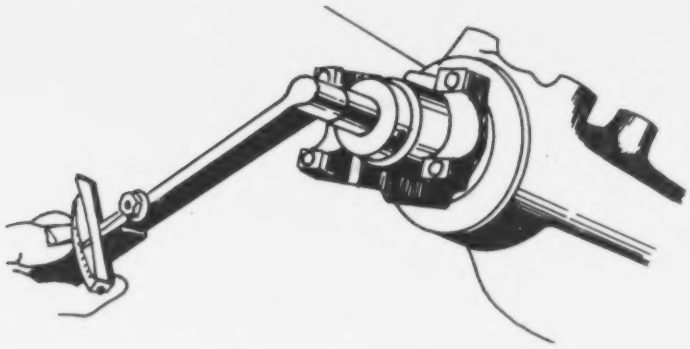
II. Procedure

- A. Raise vehicle
- B. Place jack stands on frame
- C. Remove drive shaft

JOB SHEET #18

D. Check drive pinion bearing preload (Figure 97)

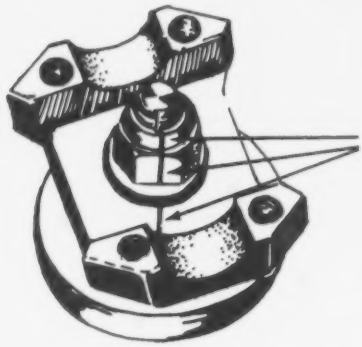
FIGURE 97



E. Record preload for reference during reassembly

F. Mark drive pinion flange, nut, and pinion shaft with a scribe (Figure 98)

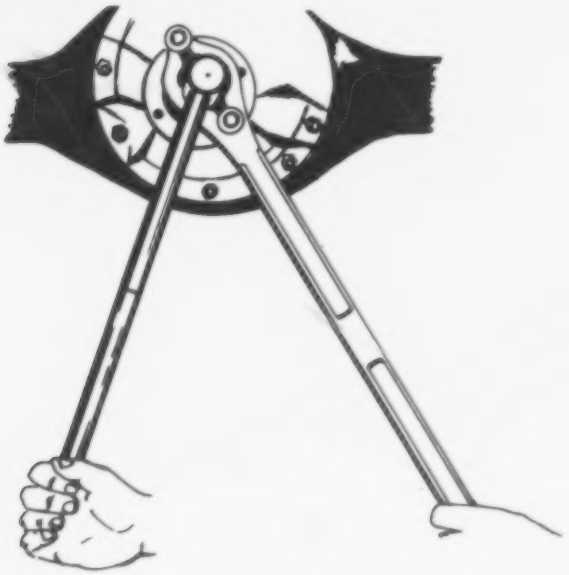
FIGURE 98



JOB SHEET #18

G. Hold drive pinion flange with holding tool (Figure 99)

FIGURE 99



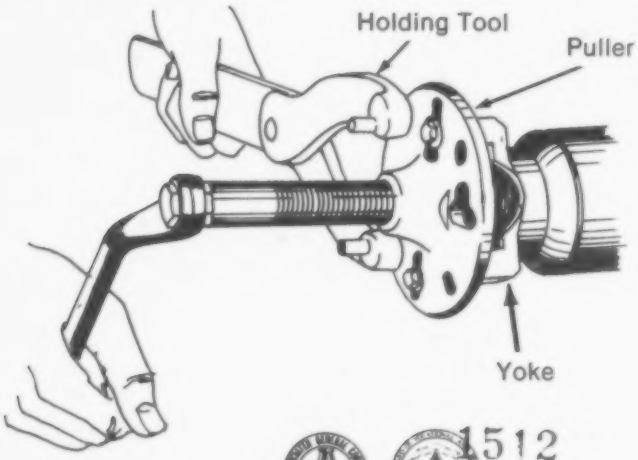
H. Remove pinion nut

I. Drain differential if possible; if not possible, place drain pan under pinion seal area to catch gear lubricant

J. Remove drive pinion flange with a puller (Figure 100)

(CAUTION: Do not drive off flange; this will distort it.)

FIGURE 100



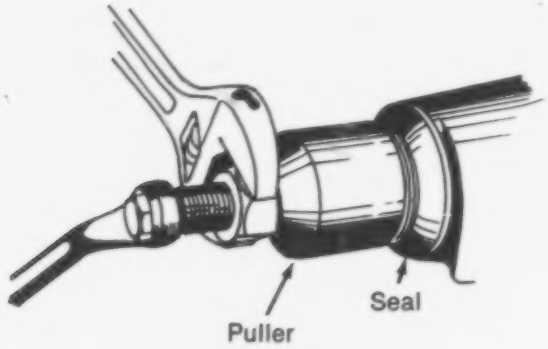
JOB SHEET #18

K. Inspect flange for an excessive groove worn by seal lip, and for nicks or burrs on sealing surface

(NOTE: Small nicks and burrs may be removed with #400 sandpaper.)

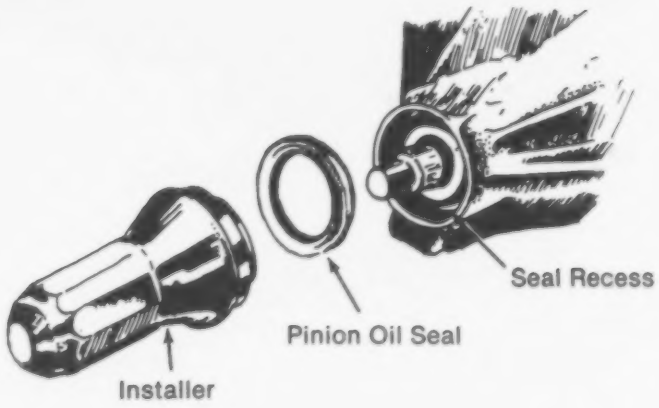
L. Remove seal with puller (Figure 101)

FIGURE 101



M. Clean seal recess in housing (Figure 102)

FIGURE 102



N. Apply a thin coat of nonhardening sealer to outer surface of seal

(NOTE: Install a new collapsible spacer to ensure that a quality job is produced.)

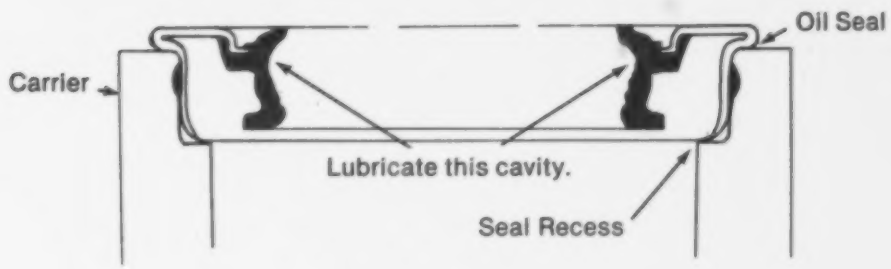
JOB SHEET #18

O. Install the seal with a seal driver, driving squarely and to the proper depth (See Figure 102)

(NOTE: The seal lip should be facing in.)

P. Lubricate seal lip, flange sealing surface, and pinion splines with gear lubricant (Figure 103)

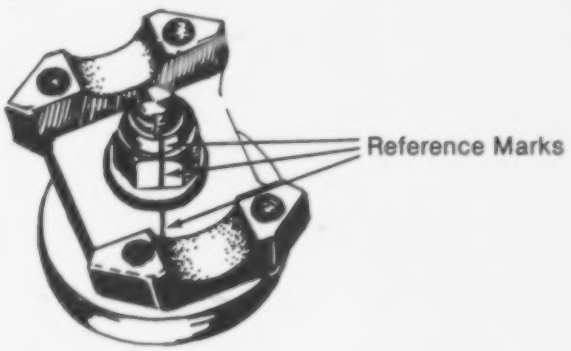
FIGURE 103



Q. Install flange on pinion, taking care to align reference marks (Figure 104)

(NOTE: Use a puller to install flange as required.)

FIGURE 104



R. Tighten pinion nut if pinion bearings are separated by a collapsible spacer

(NOTE: Tighten the pinion nut slightly; then check preload. Repeat this procedure until the preload is exactly what you recorded earlier, or until it meets specifications.)

(CAUTION: Do not overtighten the preload or it will be necessary to replace the collapsible spacer. Never back off pinion nut to adjust preload.)

JOB SHEET #18

S. If the pinion bearings are separated by shims, torque pinion nut to manufacturer's specifications

T. Reinstall drive shaft

U. Fill rear axle with gear lubricant specified by manufacturer

V. Remove jack stands and lower vehicle to floor

W. Clean work area; clean and put away all tools and equipment

X. Road test with the instructor

POWER TRAINS
UNIT I

JOB SHEET #19 — INSTALL A BALL-BEARING-TYPE AXLE SHAFT BEARING AND SEAL

I. Equipment and materials

A. Vehicle

B. Floor jack and jack stands

C. Bench vise

D. Safety glasses

E. Lug wrench

F. Basic hand-tool set

G. Cold chisel

H. Slide hammer with axle puller and seal puller adapter

I. Seal driver

J. Hydraulic press

(NOTE: A suitable bearing puller may be used.)

K. Axle bearing press plate

L. Torque wrench with ½-inch drive

M. Shop towels

N. Rear axle lubricant

II. Procedure

(CAUTION: It is extremely important to use eye protection while performing this job.)

A. Raise vehicle

B. Place jack stands on frame

C. Remove the tire and wheel assembly

JOB SHEET #19

D. Back off brake shoes as required to remove brake drum (Figure 105)

FIGURE 105

E. Remove lug bolt clips and drum

(NOTE: On some models, the drum and axle hub are attached to the axle by a large nut and tapered shaft.)

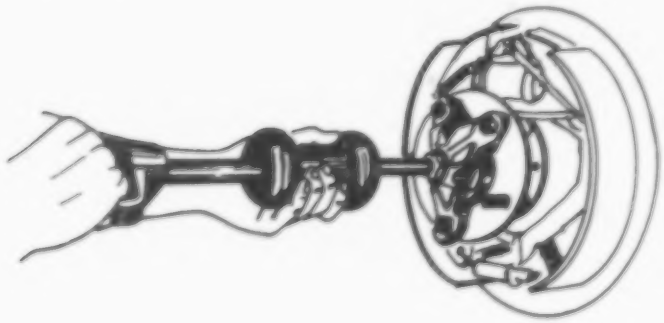
F. Clean dust from brake and axle flange

G. Remove axle retaining plate nuts through access hole in axle flange

H. Slide retainer plate off bolts

I. Attach axle puller and slide hammer to axle flange (Figure 106)

FIGURE 106



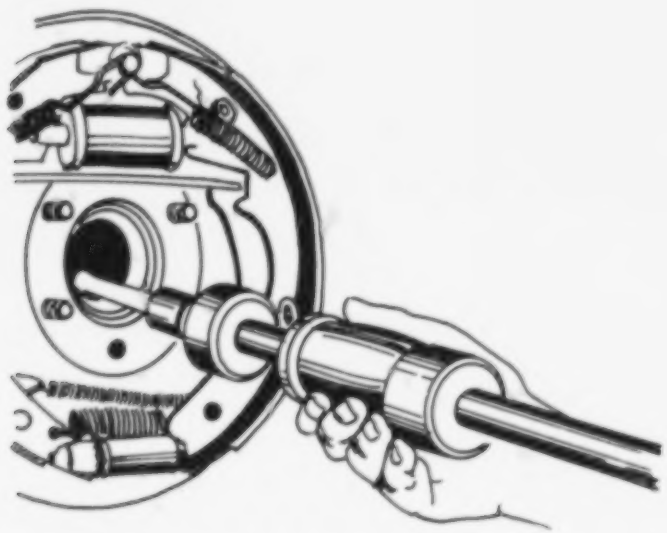
J. Pull axle

K. Restart one nut to hold brake backing plate in place

JOB SHEET #19

L. Pull axle shaft seal with puller and slide hammer (Figure 107)

FIGURE 107

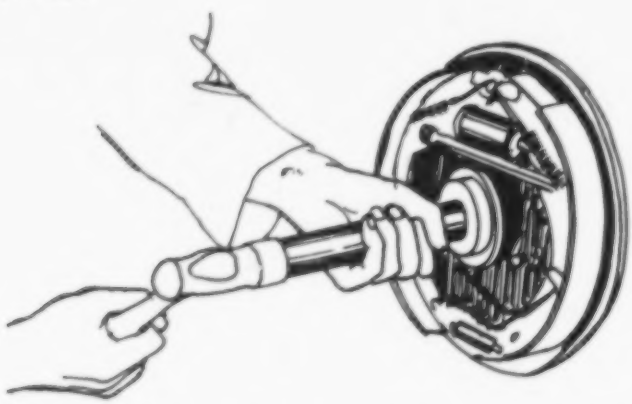


M. Clean seal recess in axle housing

N. Apply a light coat of nonhardening sealer to outer surface of seal

O. Install seal, lip inward, with a seal driver until it seats in housing (Figure 108)

FIGURE 108



P. Support axle on bench vise so that it rests on bearing retainer ring

(CAUTION: Use eye protection.)

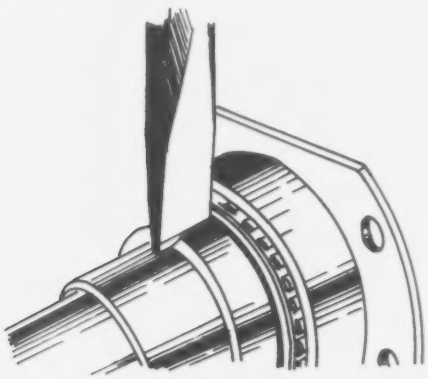
JOB SHEET #19

Q. Notch bearing retainer ring in one or more spots to loosen it (Figure 109)

(CAUTION: Never use a cutting torch to remove bearings.)

(NOTE: Protect the seal surface on the axle.)

FIGURE 109



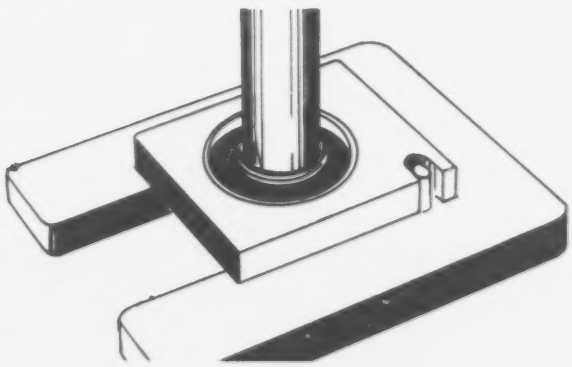
R. Place axle bearing press plate on the bearing (See Figure 109)

S. Place assembly in hydraulic press

T. Press off bearing (Figure 110)

(CAUTION: Cover the bearing while pressing; it could explode.)

FIGURE 110



U. Clean axle and retainer plate with solvent

JOB SHEET #19

V. Inspect for deformation and worn axle splines; seal surface nicks and burrs

(NOTE: Never wash sealed bearings in solvent. Washing removes the lubricant and causes premature bearing failure.)

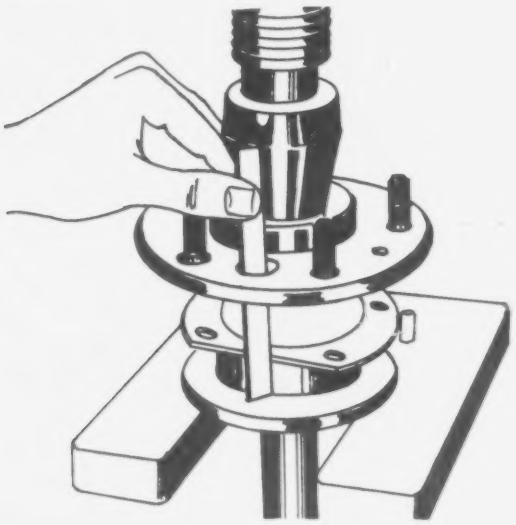
W. Install retainer plate, bearing, and bearing ring on axle shaft in that order

X. Place bearing press plate on hydraulic press

Y. Slide axle shaft through press plate so that retainer ring contacts plate

Z. Press axle through bearing and retainer ring while guiding retainer plate over bearing seat (Figure 111)

FIGURE 111



AA. Lubricate the seal lip

BB. Remove nut holding brake backing plate in place

CC. Place axle into housing, being careful not to damage the seal

(NOTE: Be sure that the axle splines are started in the side gear before exerting force on the axle to seat the bearing.)

DD. Place retainer plate on bolts; start the nuts

EE. Torque nuts in an alternating pattern

FF. Reinstall brake drum

JOB SHEET #19

GG. Reinstall drum retainer clips

HH. Reinstall tire assembly

II. Adjust brakes

JJ. Refill rear axle housing with grease specified by manufacturer

KK. Remove jack stands and lower vehicle

LL. Clean work area; clean and put away all tools and equipment

MM. Road test with the instructor

POWER TRAINS
UNIT I

JOB SHEET #20 — ADJUST DRIVE PINION BEARING PRELOAD WITH CARRIER ASSEMBLY REMOVED

I. Equipment and materials

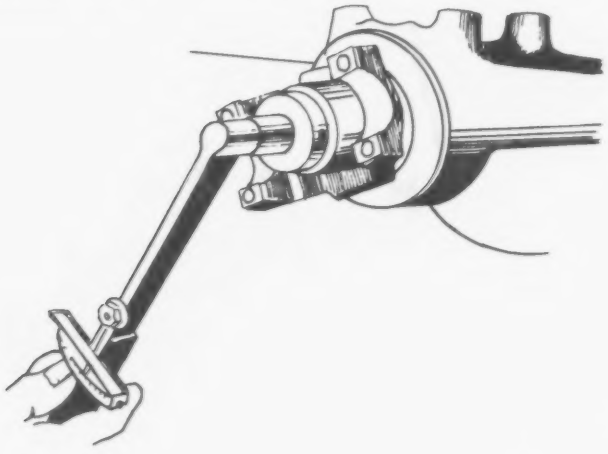
- A. Carrier assembly, removed from vehicle
- B. Pinion flange holding tool
- C. Foot-pound torque wrench, 0 to 250 pound range
- D. Inch-pound torque wrench
- E. Outside micrometer , 0 to 1 inch
- F. Basic hand-tool set
- G. Drive pinion flange puller
- H. Soft hammer
- I. Assortment of shims for pinion preload adjustment
- J. New drive pinion nut
- K. Gear lubricant
- L. Collapsible spacer
- M. Bench vise
- N. Appropriate service manual
- O. Shop towels

II. Procedure

- A. Secure carrier assembly in bench vise or holding fixture
- B. Remove differential case from carrier assembly to allow free movement of drive pinion

C. Turn drive pinion by flange nut, using the inch-pound torque wrench and socket (Figure 112)

FIGURE 112



D. Record reading of torque wrench while shaft is turning

(NOTE: This reading is the bearing preload.)

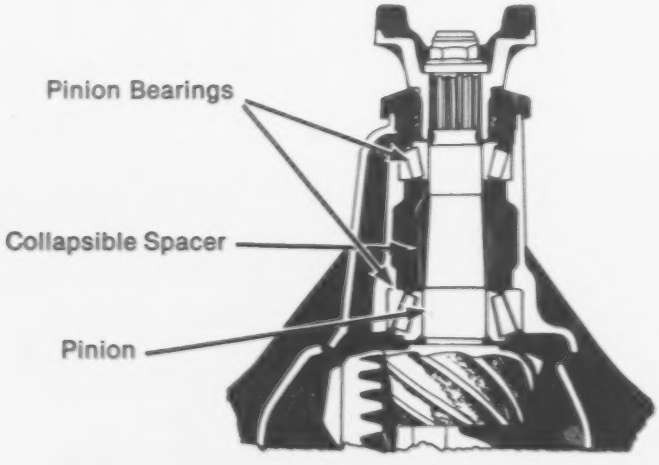
E. Compare torque reading with manufacturer's specifications

F. Proceed as follows if change is required

1. On applications using a collapsible spacer to separate the pinion bearings (Figure 113)

(NOTE: Refer to manufacturer's service guide.)

FIGURE 113



JOB SHEET #20

a. To increase preload

1) Tighten the pinion nut no more than a quarter turn, using the flange-holding tool and the foot-pound torque wrench

2) Recheck the pinion preload

3) Continue this procedure until preload is correct

b. To reduce preload

(NOTE: Too much preload indicates that the spacer is collapsed too much and will have to be replaced.)

1) Remove drive pinion flange

2) Remove drive pinion seal

3) Remove drive pinion front bearing

4) Remove collapsible spacer and replace with new one

5) Reassemble parts in reverse order

6) Tighten new drive pinion nut until slack is removed from flange, bearing, and spacer

7) Readjust bearing preload to specifications

2. On applications using shims to separate drive pinion bearings

(NOTE: To increase preload make a thinner shim pack; to decrease preload make a thicker one. Change shim pack thickness only 0.002 inch at a time.)

a. Remove drive pinion flange

b. Remove pinion seal

c. Remove pinion front bearing

d. Replace shim pack with adjusted shim pack

e. Lubricate and install drive pinion front bearing

(NOTE: The drive pinion seal may be left out until the proper shim thickness is obtained.)

f. Apply sealer to outer surface of seal and reinstall

g. Lubricate flange and install

h. Torque new drive pinion nut to specifications

i. Recheck preload

G. Clean work area; clean and put away all tools and equipment

POWER TRAINS
UNIT I

JOB SHEET #21 — ADJUST BACKLASH AND CARRIER BEARING PRELOAD

I. Equipment and materials

- A. Carrier assembly, removed from vehicle
- B. Two spanner wrenches
- C. Backlash gauge
- D. Foot-pound torque wrench
- E. Basic hand-tool set
- F. Bench vise
- G. Appropriate service manual
- H. Shop towels

II. Procedure

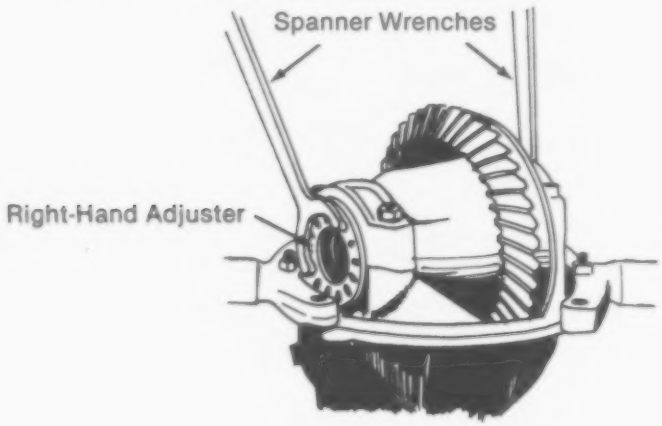
- A. Secure carrier assembly in bench vise or holding fixture
- B. Remove carrier adjuster locks
- C. Loosen carrier cap bolts; then retighten to approximately 10 foot-pounds, with differential case assembly installed in carrier housing

JOB SHEET #21

D. Use spanner wrenches to turn adjusters inward equally until bearing cups are seated against bearing cones so that end play is zero and some backlash is observable (Figure 114)

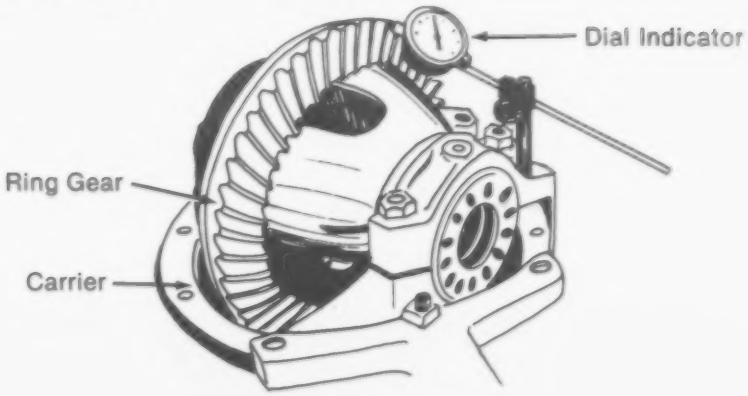
(NOTE: Rotate the ring gear during adjustment to allow the bearings to align.)

FIGURE 114



E. Set up backlash gauge (Figure 115)

FIGURE 115



JOB SHEET #21

F. Turn both adjusters in the same direction to move ring gear toward drive pinion until backlash is 0.005 inch with zero end play

G. Torque carrier cap bolts on ring gear side to specified torque

H. Tighten adjuster opposite ring gear to obtain specified backlash

(CAUTION: Do not exceed maximum backlash; overadjustment overloads the bearings.)

I. Torque last two cap bolts

J. Install adjuster locks

K. Check gear tooth contact pattern

L. Clean work area; clean and put away all tools and equipment

POWER TRAINS
UNIT I

JOB SHEET #22 — REMOVE AND REINSTALL A REAR AXLE HOUSING ASSEMBLY

I. Equipment and materials

- A. Vehicle
- B. Floor jack and jack stands
- C. Safety glasses
- D. Torque wrench
- E. Basic hand-tool set
- F. Tubing wrenches, 3/8" and 5/8"
- G. Penetrating oil
- H. Brake fluid
- I. Gear lubricant
- J. Appropriate service manual
- K. Shop towels
- L. Wooden block

II. Procedure

- A. Remove rear axle housing
  1. Raise vehicle
  2. Support vehicle with jack stands on frame so that axle hangs free
  3. Remove tires and wheel assembly
  4. Spray all attaching bolts and nuts with penetrating oil
  5. Prop brake pedal in UP position with a wooden block
  6. Disconnect brake hose at body support
  7. Disconnect emergency brake cable at round eyelets
  8. Disconnect emergency brake cable housing at body supports
  9. Disconnect rear shock absorbers at the bottom

     (NOTE: On coil spring applications, a jack should support the axle housing before shocks are disconnected.)

JOB SHEET #22

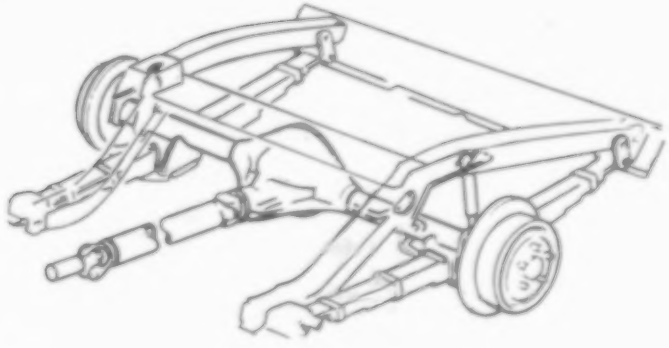
10. Disconnect rear axle supports

    a. On leaf-spring-type (Figure 116)

        1) Disconnect spring U-bolts

        2) Remove rear assembly

FIGURE 116



    b. On coil-spring model (Figure 117)

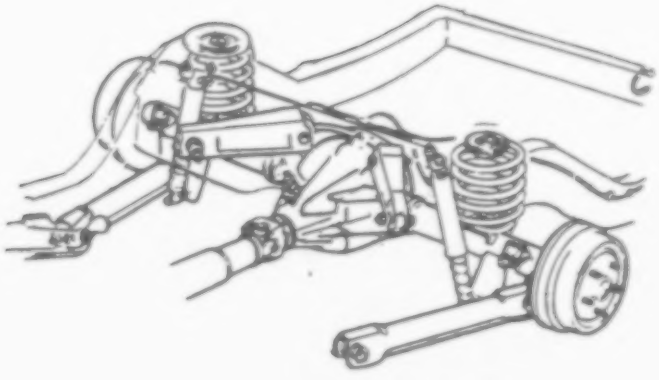
        1) Disconnect all stabilizer bars, upper control arm, and other accessories where they attach to rear axle housing

        2) Lower axle on jack until springs are free

        3) Remove bolts from lower control arm

        4) Remove rear axle assembly

FIGURE 117



JOB SHEET #22

B. Reinstall rear axle assembly

1. Place axle housing on jack
2. Align axle housing under vehicle
3. Connect rear axle supports
   a. On leaf-spring-type
      1) Align spring tie bolt with pilot hole in axle plate
      2) Install U-bolts on springs
      3) Torque U-bolts in alternating sequence
   b. On coil-spring-type
      1) Align lower control arms with axle housing brackets; install bolts
      2) Align upper control arms with axle housing brackets; install bolts
      3) Install coil springs
      4) Raise axle and attach lower ends of shock absorbers
4. Reconnect stabilizers and other accessories connected to axle housing

   (NOTE: Do not tighten bolts on control arms until the vehicle is sitting level with full weight on the tires.)
5. Reconnect and adjust emergency brake cable
6. Reconnect hydraulic brake hose
7. Bleed system
8. Install tires and wheel assembly
9. Adjust brakes
10. Raise rear axle housing until full weight of vehicle is on it

    (CAUTION: Jack stands should remain in place.)
11. Tighten all control arm bushing bolts

C. Fill differential with lubricant

(NOTE: Check manufacturer's specifications on nonslip differential lubricant.)

D. Remove jack stands and lower vehicle to floor

E. Clean work area; clean and put away all tools and equipment

F. Road test with instructor

POWER TRAINS
UNIT I

JOB SHEET #23 — DISASSEMBLE, INSPECT, REASSEMBLE, AND ADJUST AN INTEGRAL CARRIER REAR AXLE

I. Equipment and materials

- A. Vehicle
- B. Carrier support fixture
- C. Basic hand-tool set
- D. Pinion flange holding tool
- E. Pinion flange puller and installer
- F. Pinion seal puller
- G. Pinion seal driver
- H. Bearing pullers
- I. Bearing drivers
- J. Carrier housing spreader
- K. Combination dial indicator
- L. Micrometer, 0 to 1.000 inch
- M. 2 pinch bars
- N. Scribe
- O. 2 feeler gauges
- P. Foot-pound torque wrench
- Q. Inch-pound torque wrench
- R. Pattern paste
- S. Soft plastic or lead hammer
- T. Shop towels
- U. Appropriate service manual

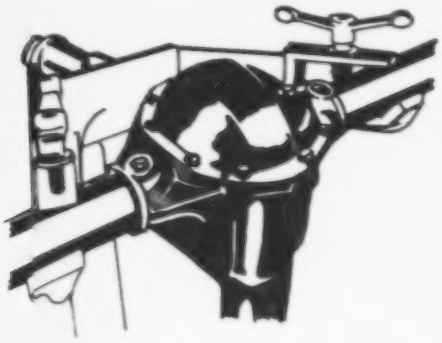
JOB SHEET #23

II. Procedure

A. Disassemble integral carrier rear axle

1. Secure axle housing in holding fixture (Figure 118)

FIGURE 118



2. Clean outside of housing

3. Remove differential cover

4. Remove brake drums

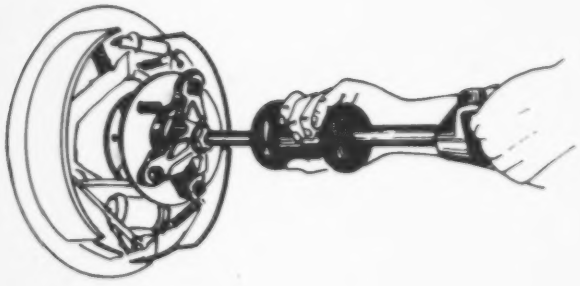
5. Remove axles

a. To remove axles *without* internal C-locks

1) Remove axle bearing retaining plate bolts

2) Attach axle puller (Figure 119)

FIGURE 119



JOB SHEET #23

3) Pull the axle

(NOTE: Use care to prevent the brake backing plate from falling and being damaged.)

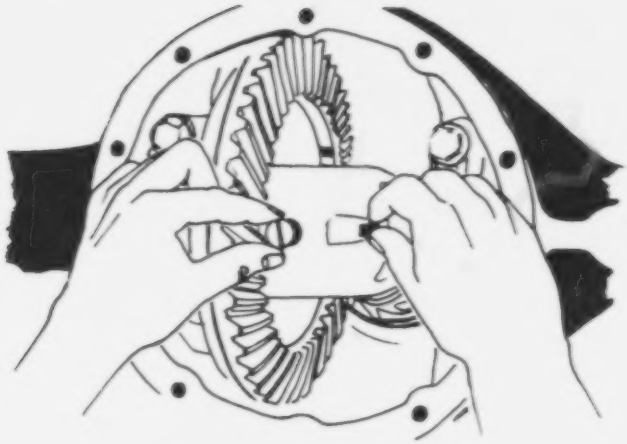
4) Replace one nut on the backing plate to hold it in place

b. To remove axles *with* internal C-locks

1) Remove the differential pinion shaft lockscrew (See Figure 120)

2) Remove the differential pinion shaft (Figure 120)

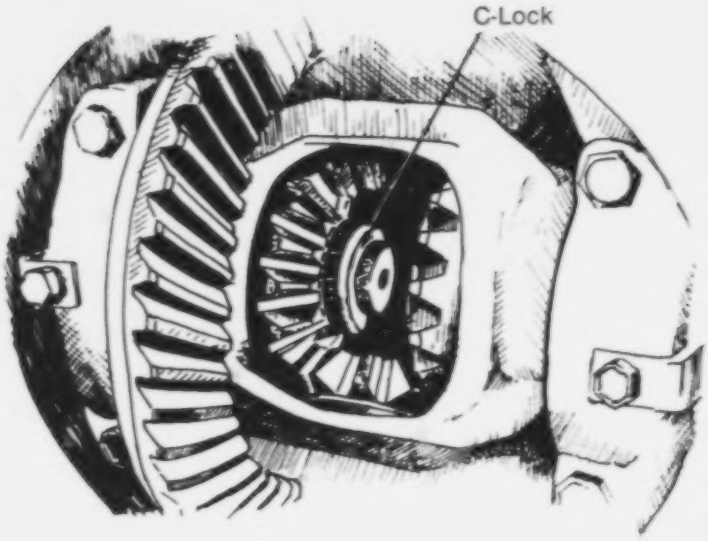
FIGURE 120



3) Push flanged end of axle shaft toward center of vehicle

4) Remove C-locks from inside differential case (Figure 121)

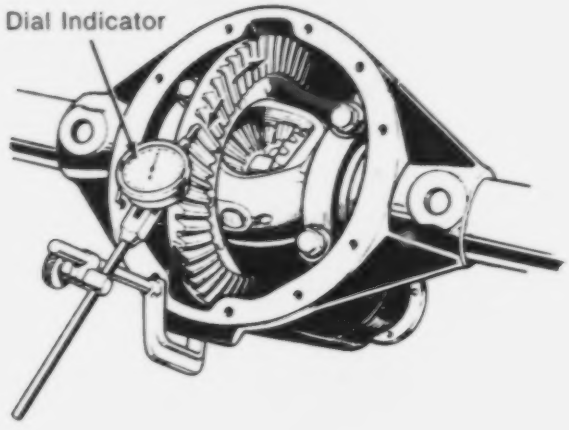
FIGURE 121



5) Pull axle out of differential case

6. Measure and record ring and pinion backlash (Figure 122)

FIGURE 122

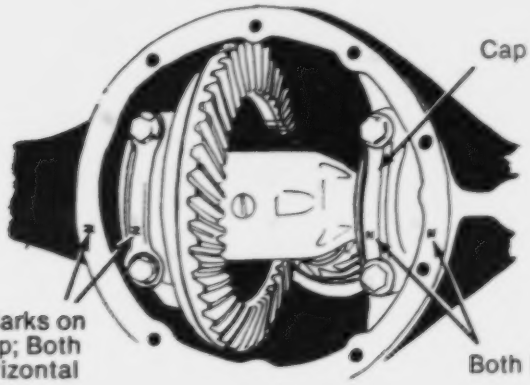


JOB SHEET #23

7. Make a tooth contact pattern for later reference

8. Mark carrier bearing caps for left and right sides (Figure 123)

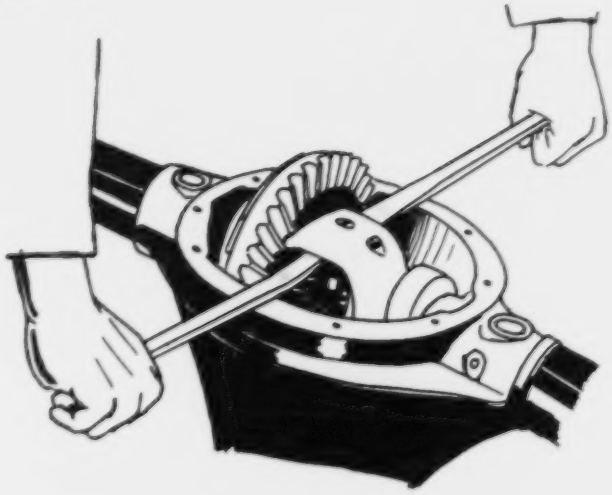
FIGURE 123



9. Remove carrier bearing caps

10. Pry differential case out of carrier housing with two pinch bars (Figure 124)

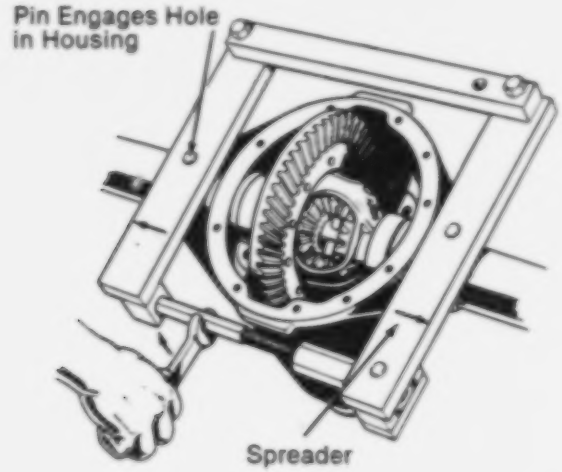
FIGURE 124



(NOTE: If carrier housing is holding the differential case too tightly, use the spreader to give just enough clearance to remove the case. See Figure 125.)

(CAUTION: Do not exceed manufacturer's limits on spreading the housing.)

FIGURE 125



11. Mark carrier bearing spacers as they were in the housing so that they can be used as references during assembly

12. Check and record drive pinion preload

13. Scribe drive pinion, nut, and flange

14. Remove drive pinion flange

15. Remove drive pinion seal

16. Remove drive pinion front bearing cone

17. Remove preload shims or collapsible spacer from pinion

    (NOTE: Some shims may stick to the front bearing cone.)

18. Remove pinion from carrier housing

19. Remove ring gear from differential case

20. Clean all parts and air dry

JOB SHEET #23

B. Inspect integral carrier rear axle

1. Inspect bearing cones for roller heat discoloration, scaling, and pitting; inspect roller cage for wear or damage

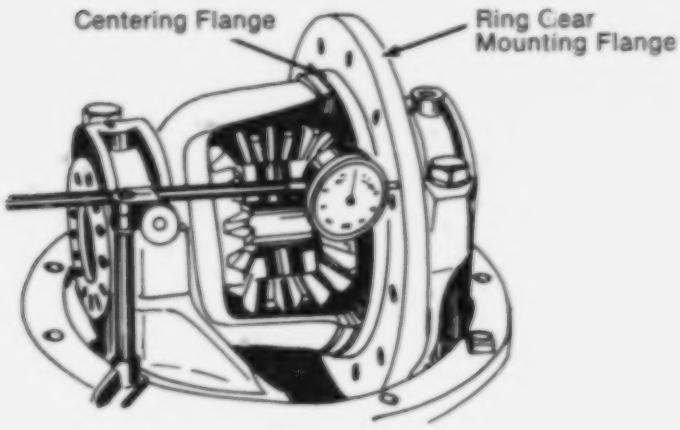
2. Inspect bearing cups for heat discoloration, scaling, and pitting

   (NOTE: Bearing cup wear pattern can indicate problems that cause bearing failure such as misalignment, looseness, or lack of lubrication.)

3. Inspect drive pinion and ring gear teeth for scoring and chipping

   (NOTE: Severe damage to either gear will warrant checking with the dial indicator the runout of the differential case, the ring gear centering surface, and the attaching flange. See Figure 126.)

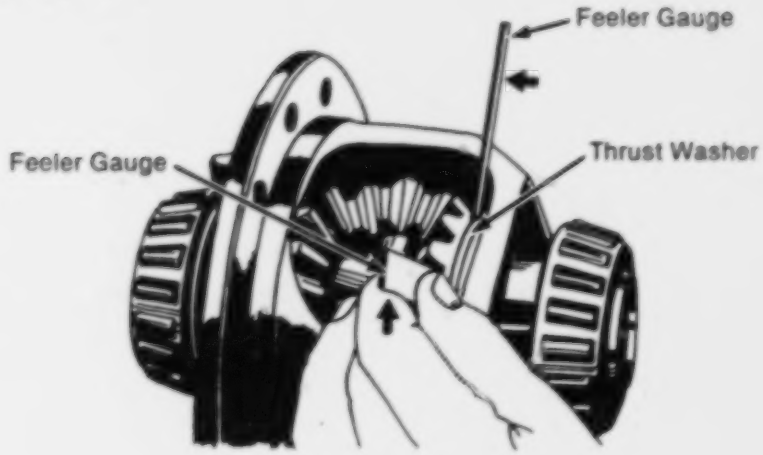
FIGURE 126



4. Inspect axle side gears and differential pinion gears for wear and chipping

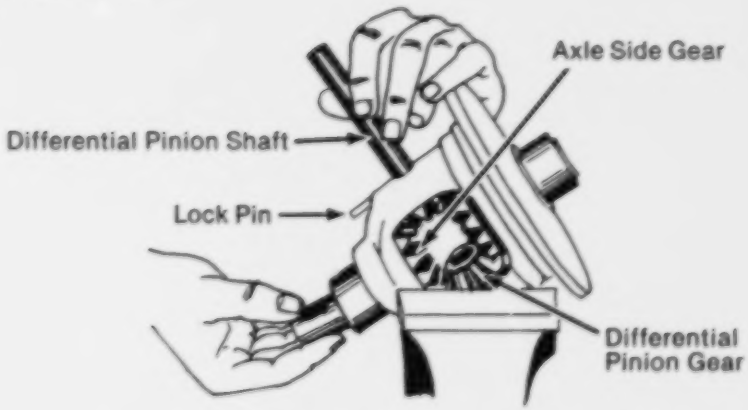
5. Measure side gear clearance with two feeler gauges of the same thickness (Figure 127)

FIGURE 127



6. Disassemble differential unit by removing pinion shaft lock pin and pinion shaft (Figure 128)

FIGURE 128



7. Rotate one axle gear to roll out the pinion gears while holding the other axle gear stationary

8. Remove axle side gears

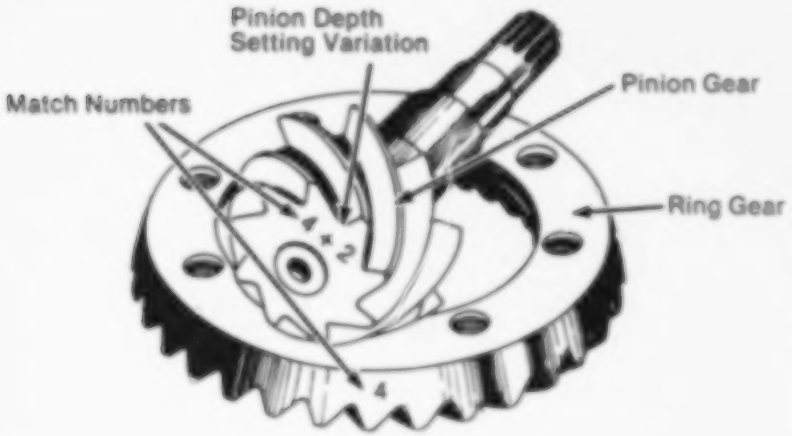
9. Inspect all thrust washers and thrust surfaces for scoring and excessive wear

JOB SHEET #23

10. Make a list of parts that require replacement

(NOTE: The ring and pinion gears are a matched set and must be replaced as a set. See Figure 129.)

FIGURE 129



C. Reassemble and adjust integral carrier rear axle

1. Reclean all parts, tools, and work area
2. Lubricate all parts as they are assemb'ed
3. Install thrust washers on axle side gears
4. Place gears in differential case
5. Place one differential pinion gear in mesh with the axle side gears
6. Rotate one side gear until the pinion gear is opposite the case opening
7. Place other pinion gear 180 degrees from first gear
8. Rotate one axle gear until both pinion gears align with shaft holes in case

(NOTE: The pinion shaft may be used to align the gears.)

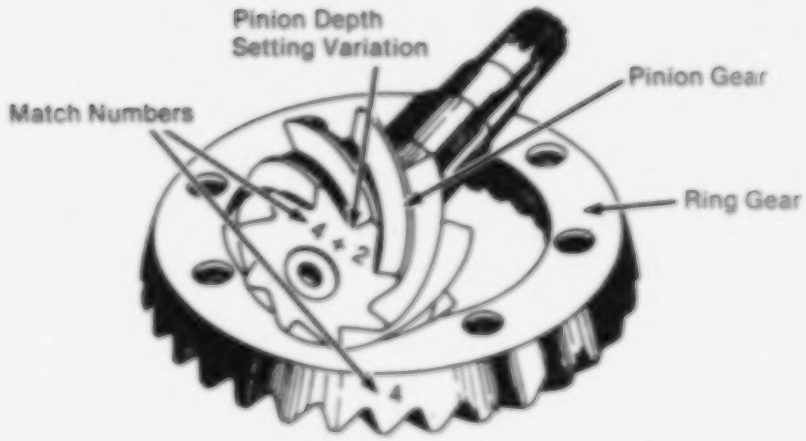
9. Install pinion gear thrust washers and pinion shaft
10. Install pinion shaft lock pin

JOB SHEET #23

11. Put three guide stud bolts in ring gear
12. Install ring gear on differential case
13. Attach bolts; torque
14. Remove guide bolts
15. Replace guide bolts with attaching bolts; torque
16. Replace differential bearing cones if necessary
17. Replace pinion bearings if necessary

    (NOTE: If the same pinion is being reused, the same pinion depth shim will be reused. If a new pinion is used, refer to the numbers on the rear surfaces of the new and old gears, to the thickness of the old shim, and to the manufacturer's number code for the new pinion depth shim thickness. See Figure 130.)

FIGURE 130



18. Install carrier bearing caps
19. Torque bolts
20. Measure backlash
21. Check tooth contact pattern
22. Make necessary shim changes to correct the contact pattern and backlash

JOB SHEET #23

23. Remove pinion nut and spacer used in place of the pinion flange
24. Install pinion seal
25. Install pinion flange and nut
26. Torque pinion nut on models with preload shims
27. Collapse preload collapsible spacer, and set pinion bearing preload
28. Install axles
29. Install brake drums
30. Adjust brakes
31. Install carrier inspection cover
32. Clean work area; clean and put away all tools and equipment

POWER TRAINS
UNIT I

TEST

NAME _____ SCORE _____

1. Match to their correct definitions terms associated with power trains. Write the correct numbers in the blanks. Terms and definitions are continued on the following pages.

_____a. Bearing that provides a method of releasing pressure plate spring pressure

_____b. Plate that provides friction between pressure plate and flywheel

_____c. Housing, spring, and plate assembly that provides pressure to clamp clutch disc between pressure plate and flywheel

_____d. Amount of clutch pedal or lever movement before release bearing contacts pressure plate fingers

_____e. Y-shaped lever inside clutch housing used to engage and disengage clutch

_____f. Heavy metal disc that has a friction surface for clutch plate and supports all clutch components

_____g. Turning or twisting effort

_____h. Bearing located in flywheel flange of crankshaft; allows for correct support and alignment of transmission input shaft

_____i. Time it takes for clutch disc to stop spinning after clutch release

_____j. Transmission using synchronizers that prevent grinding of gear teeth when gears are shifted

_____k. Gears that are always in mesh with each other

_____l. Device in transmission that causes two gears being shifted together to rotate at the same speed

1. Free travel
2. Flywheel
3. Synchromesh transmission
4. Release bearing
5. Synchronizer
6. Torque
7. Clutch disc
8. Clutch disc spin
9. Release fork
10. Constant mesh
11. Pressure plate
12. Pilot bearing

TEST

_____m. Group of gears made on a common casting; used in a standard transmission to connect main drive gear to first, second, and reverse idler gears

_____n. Gear in transmission used to change direction of rotation of output shaft

_____o. Number of turns made by a driving gear in relation to one full turn of the driven gear

_____p. Shaft that connects transmission to rear axle through differential to propel vehicle

_____q. Gear that rotates backward

_____r. Driving connection made of one or more propeller shafts between transmission and differential

_____s. Propeller shaft runout or unbalanced condition; causes shaft to act similarly to the loop action of a rope held at both ends and swung in an arc

_____t. Procedure of aligning the yokes of a two- (or more) piece propeller shaft to help control whirl and vibration in propeller shaft

_____u. Variable length connection at one end of a propeller shaft that allows shaft to vary in length as vehicle body moves up and down in relation to rear axle

_____v. Coupling that allows power to be transferred through an angle

_____w. Distance separating two gear teeth that are meshed together

_____x. Unit that drives both rear wheels at the same time but allows them to turn at different speeds when negotiating turns

_____y. Distance that one gear can be moved back and forth without moving the gear into which it is meshed

13. Cluster gear
14. Idler gear
15. Drive line
16. Gear tooth clearance
17. U-joint timing
18. Slip joint
19. Gear ratio
20. Whirl
21. Differential
22. Backlash
23. U-joint (universal joint)
24. Countergear
25. Propeller shaft

TEST

_____z. Axle that supports, retains, and drives the wheel; outer end of axle is supported by a bearing in the axle housing

_____aa. Adjustment of antifriction bearings so that they are under mild pressure; tested by amount of torque in inch pounds required to turn shaft

_____bb. Special traction differential that automatically transfers torque to the wheel that is not slipping when loss of drive force occurs in other wheel

_____cc. Axle that drives the wheel; wheel is supported and retained by a hub containing two roller bearings that are attached to axle housing

_____dd. Axle that retains and drives the wheel; load is supported by means of a hub and bearing assembly on the axle housing

26. Full-floating axle
27. Preload
28. Three-quarter floating axle
29. Nonslip differential
30. Semifloating axle

2. State the purpose of the power train.

_____

_____

3. List two jobs performed by the power train.

a. _____

b. _____

4. Match basic parts of the power train to their correct functions. Write the correct numbers in the blanks.

_____a. Selects speed and direction

_____b. Connects transmission to differential

_____c. Equalizes power for turning

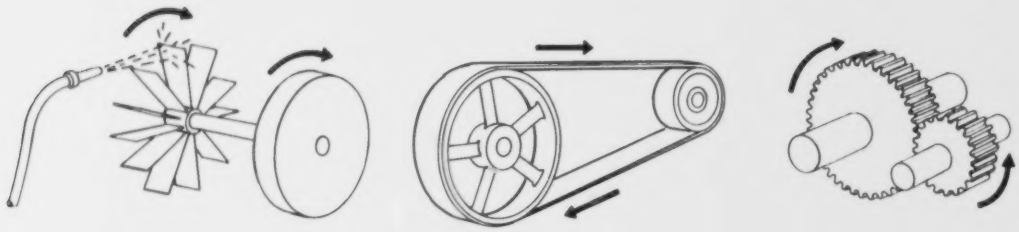
_____d. Gives final reduction in speed and increase in torque to drive wheels

_____e. Provides power

1. Differential
2. Engine
3. Final dirve
4. Transmission
5. Drive shaft

TEST

5. Label the following basic ways of transmitting power. Write the correct names in the blanks.



a. _____ b. _____ c. _____

6. Describe the principle of the disc clutch.

_____

_____

_____

_____

_____

7. Describe the principle of the transmission.

_____

_____

_____

8. Describe the principle of the differential.

_____

_____

_____

TEST

9. Match types of clutches to their correct operations. Write the correct numbers in the blanks.

_____a.	Forces oil into a chamber between the fixed and moving driven members; as oil pressure in the chamber builds, the walls of the chamber are forced outward, causing contact between the driven and drive members	1. Cone
_____b.	Engages two cone-shaped parts	2. Magnetic
_____c.	Tightens an outside band over a rotating part	3. Expanding shoe
_____d.	Expands an inner shoe to contact an outer part	4. Hydraulic
_____e.	Works by friction between the drive line and clutch facings	5. Pneumatic
_____f.	Magnetic field holds two parts together, allowing them to rotate as a unit	6. Slip
_____g.	Brings one or more plates together	7. Overrunning
_____h.	Air activates pack containing a small rubber tube positioned behind a driven member and a fixed member; when valve is opened, air is forced into tube causing it to expand, and thus forcing driven plate against drive plate	8. Band
_____i.	Allows engagement in one direction, but the unit freewheels in the other direction	9. Disc

10. Select from the following list major types of clutch operating mechanisms. Write an "X" in the blank before each correct answer.

_____a. Gasoline

_____b. Electrical

_____c. Friction

_____d. Torque

_____e. Hydraulic

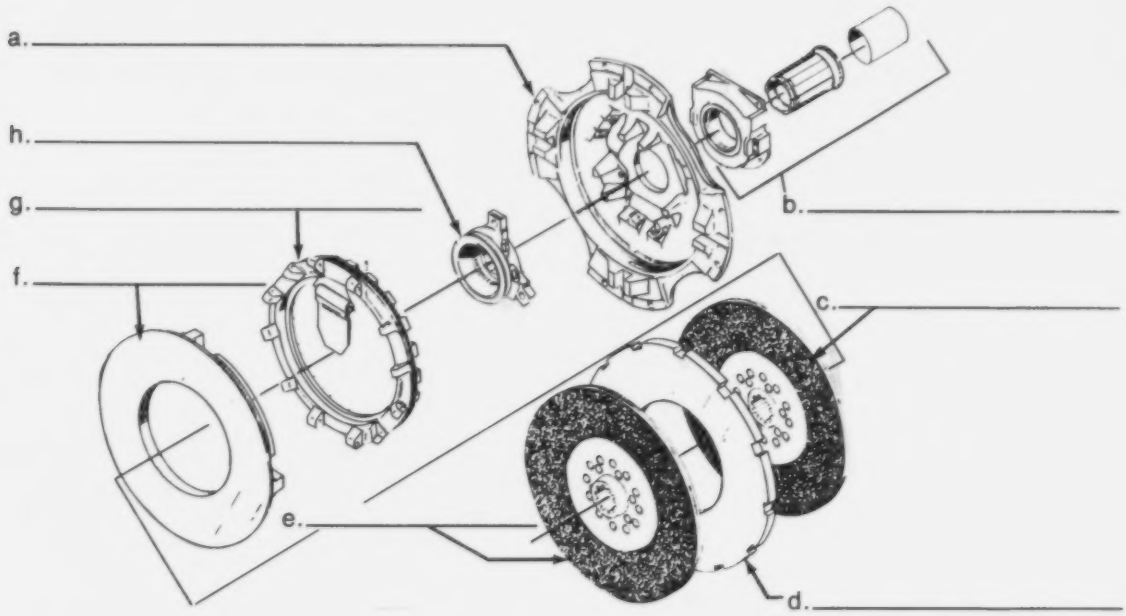
_____f. Slip joint

_____g. Mechanical

TEST

11. Identify components of the clutch assembly illustrated below. Write the correct names in the blanks.

Driven rear disc
Driven front disc
Release bearing (throwout bearing) and sleeve assembly
Adjusting ring
Intermediate plate
Pressure plate
Release sleeve retainer
Flywheel ring (cover)



12. Distinguish between engaged and disengaged clutch operation. Write an "X" in the blank before engaged clutch operation.

_____a. Spring pressure released by release bearing and linkage

_____b. Spring pressure clamps the clutch disc between pressure plate and flywheel face

TEST

13. Identify methods used to actuate clutch release. Write the correct methods in the blanks.

_____a. Master cylinder and slave cylinder transfer motion from clutch pedal or control lever to release fork

_____b. Links, levers, or rods transfer motion from clutch pedal or control lever to release fork

14. Select from the following list symptoms that may occur when clutch housing bore has excessive runout. Write an "X" in the blank before each correct answer.

_____a. Clutch pedal jumping loose

_____b. Transmission jumping out of gear

_____c. Scrubby pedal feel

_____d. Excessive clutch spin time

_____e. Drive line vibration

_____f. Pilot bearing noise

_____g. Excessive transmission gear wear or noise

_____h. Hydraulic leak in drive line

_____i. Clutch pedal vibration

_____j. Clutch lever locking up

15. Match clutch malfunctions to probable causes. Write the correct numbers in the blanks. Causes are continued on the next page.

_____a. Weak or broken pressure plate springs, worn clutch disc facing; oil or grease contamination; improperly adjusted clutch pedal

_____b. Torn out clutch disc hub; torn off or worn out facings on clutch disc; incorrect adjustment of presure plate; release bearing dragging on support

_____c. Worn or dry pilot bearing; worn or dry release bearing; pitted clutch shaft bearing or bent clutch shaft; wear in transmission or drive line

1. Binding
2. Chattering
3. Dragging
4. Grabbing
5. Noise or rattles
6. Slipping
7. Squeaks
8. Vibrations

_____d. Incorrect clutch or pedal adjustment; broken pivots in pressure plate; sticking pilot bearing or bushing; splined disc hub sticking on splined shaft

_____e. Cracked, warped, or scarred pressure plate or flywheel face; wear or looseness in universal joint, differential, or drive axles; worn, loose or spongy engine mountings; misalignment of power train

_____f. Bent clutch shaft; defective clutch disc; dust in clutch; use of rigid disc instead of flexible type

_____g. Oil or grease on clutch disc facing; pressure plate sticking on driving studs; glazed or worn clutch facing; sticking or binding release levers

_____h. Clutch release bearing needs lubrication; pilot bearing in flywheel needs lubrication; release sleeve needs lubrication; misalignment

16. Describe the purpose of the transmission._____

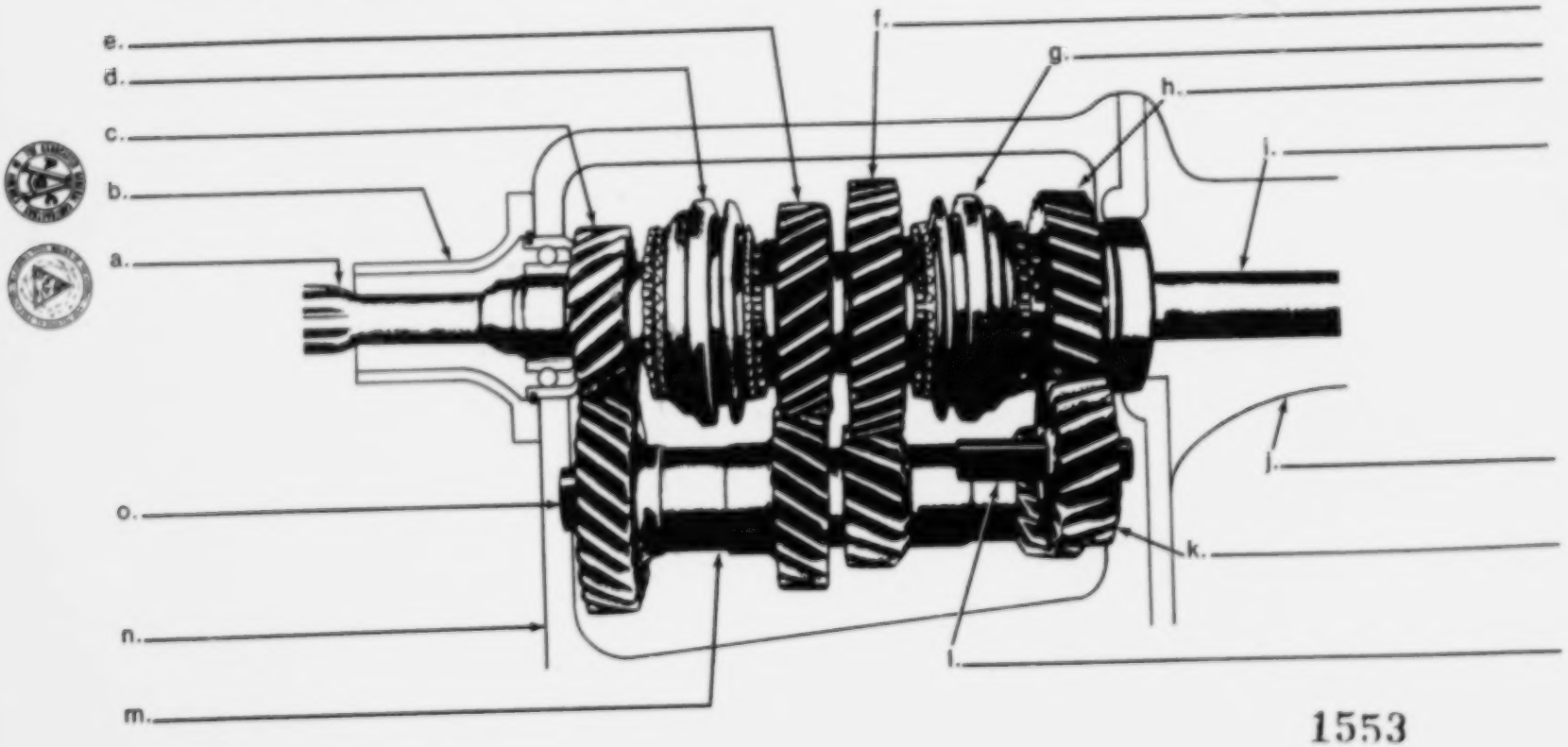
_____

_____

_____

17. Identify the major parts of the transmission illustrated below. Write the correct names in the blanks.

Input shaft (clutch shaft)
Input shaft bearing retainer
Input shaft gear (main drive gear)
Transmission case
Counter or cluster gear
Second and third gear synchronizer assembly
First and reverse synchronizer assembly
Output shaft (main shaft)
Extension housing
Reverse idler gear shaft
Second speed gear
First speed gear
Reverse gear
Countershaft
Reverse idler gear



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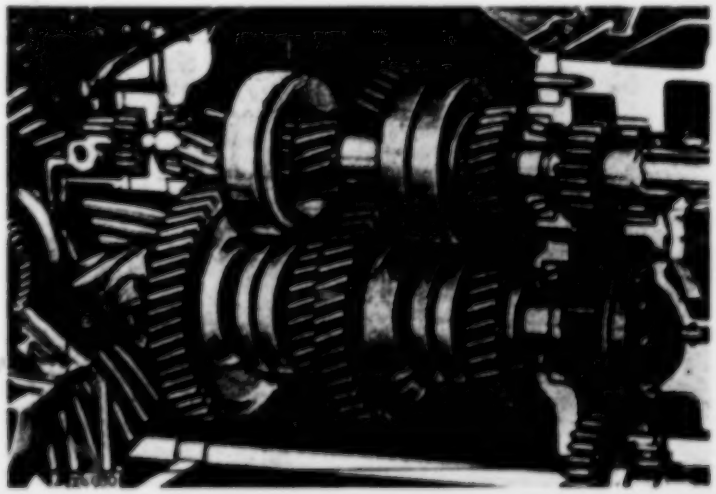
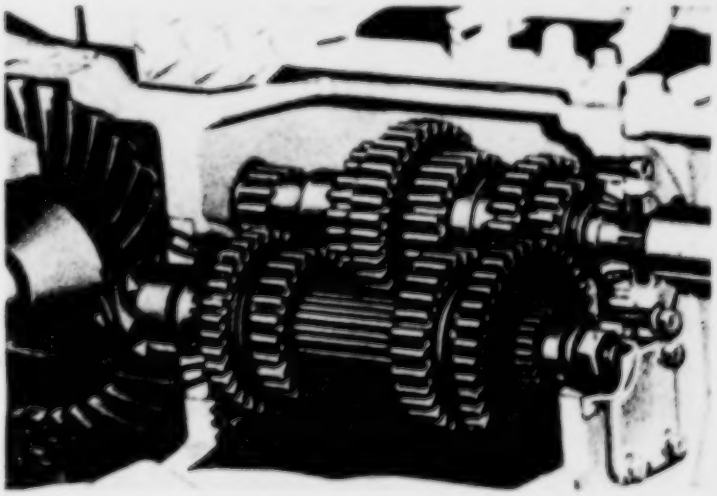
1553

TEST

18. Label the major types of mechanical transmissions illustrated below and on the next page. Write the correct names in the blanks.

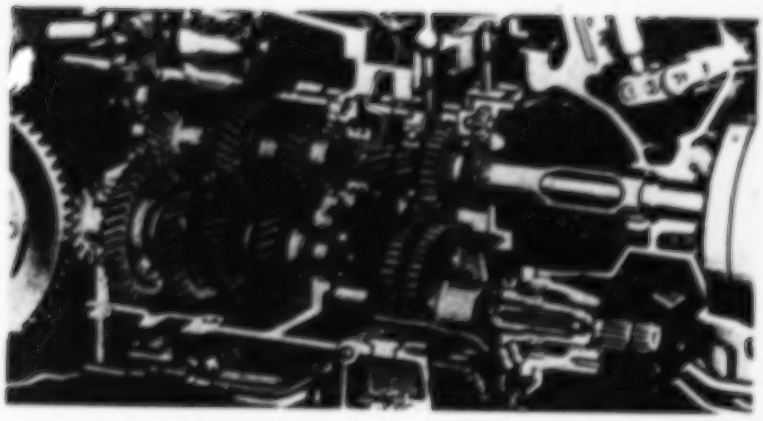


a. _____



b. _____

TEST



c. _____

19. Select from the following list common types of synchronizers. Write an "X" in the blank before each correct answer.

_____a. Cone

_____b. Ring

_____c. Block

_____d. Pin

_____e. Disc and plate

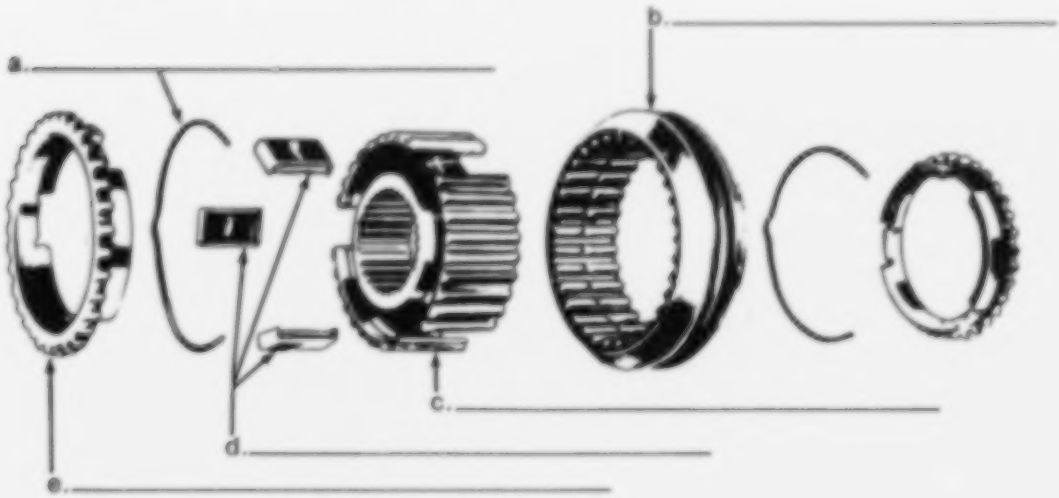
_____f. Insert

_____g. Plain

TEST

20. Identify the parts of a typical synchronizer illustrated below. Write the correct names in the blanks.

Synchronizer ring
Inserts
Hub
Sleeve
Insert spring (lock ring)



21. Discuss operation of a three-speed synchromesh transmission.

a. Neutral — _____

_____

_____

_____

b. First gear — _____

_____

_____

_____

c. Second gear — _____

_____

_____

_____

TEST

d. Third gear — _____

e. Reverse gear — _____

22. Describe the hydraulic-assist transmission.

23. Describe how hydraulic clutches and gear trains work together.

a. Hydraulic clutches — _____

b. Gear trains — _____

24. Name basic types of gear sets used in hydraulic-assist transmissions.

a. _____

b. _____

25. Select from the following list basic parts of a planetary gear system. Write an "X" in the blank before each correct answer.

_____a. Countergear

_____b. Planet pinions

_____c. Planet pinion carrier

_____d. Moon gear

_____e. Driven gear

_____f. Ring gear

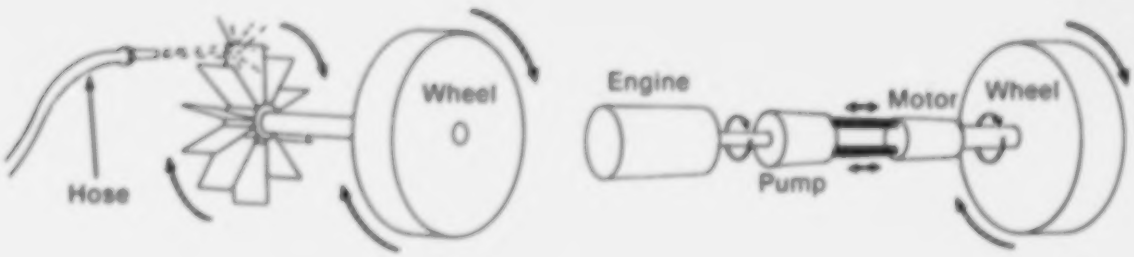
26. Describe jobs that oil performs in a hydraulic-assist transmission.

a. _____

b. _____

TEST

27. Label the basic types of hydraulic transmissions illustrated below. Write the correct names in the blanks.



a. _____ b. _____

28. State two factors that control operation of hydrostatic drive.

a. _____

b. _____

29. List three advantages of hydrostatic drives.

a. _____

b. _____

c. _____

30. Distinguish between hydrostatic drives and torque converters. Write an "H" in the blank representing hydrostatic drives and a "T" in the blank representing torque converters.

_____a. Driven by fluids at low pressure but at high speeds

_____b. Driven by fluids at high pressure but at relatively low speeds

31. Distinguish between a torque converter and a fluid coupling. Write a "T" in the blank representing torque converter and an "F" in the blank representing fluid coupling.

_____a. Can multiply the torque it receives

_____b. Can only transmit torque

32. Describe jobs that oil performs in a hydraulic control system.

a. _____

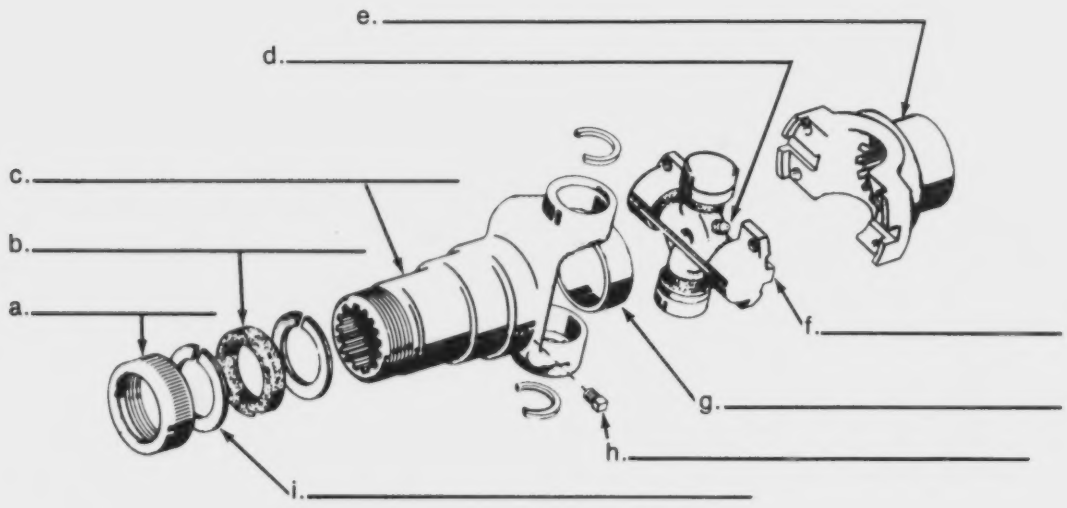
b. _____

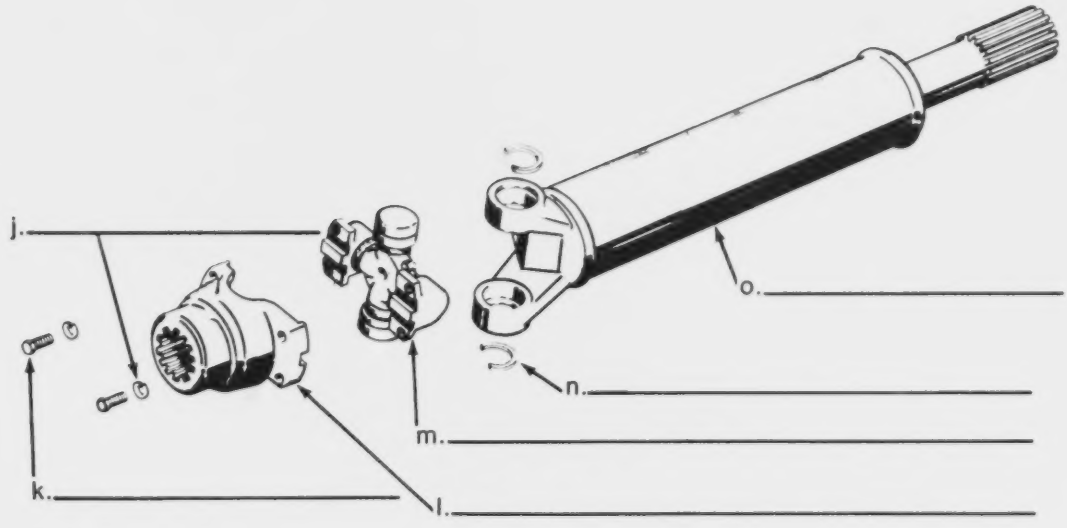
c. _____

TEST

33. Identify components of the drive (propeller) shaft illustrated below. Write the correct names in the blanks. Answers may be used more than once.

Drive shaft yoke	**Spider and bearing**	**Lock washer**
Grease fitting	**Drive shaft tube**	**Felt washer**
Snap ring	**Cap screw**	**Dust cap**
Retainer	**Cap**	**Yoke (transmission end)**
Yoke (torque converter end)	**Pipe plug**	

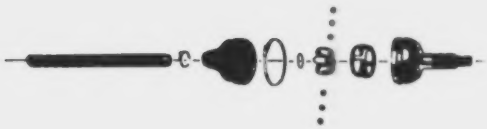


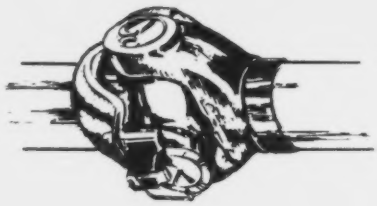


TEST

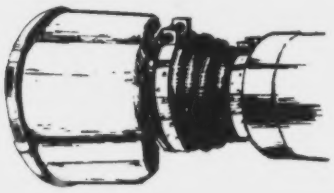
34. Identify the following types of U-joints (universal joints). Write the correct names in the blanks.

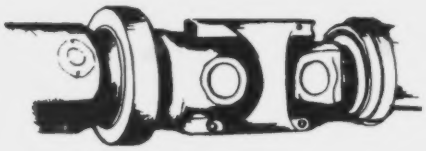
Ball-and-trunnion **Rzeppa** **Constant velocity** **Cross-and-roller**





a. _____ b. _____





c. _____ d. _____

35. List two methods of controlling drive-line vibration.

a. _____

b. _____

36. Describe how differential locks are used.

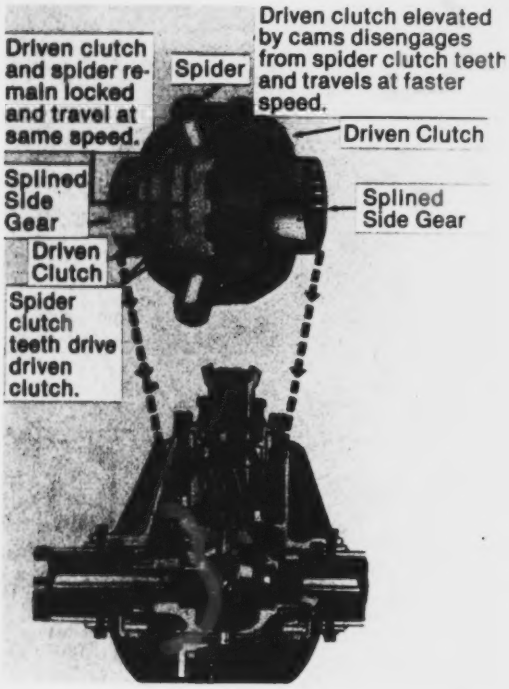
_____

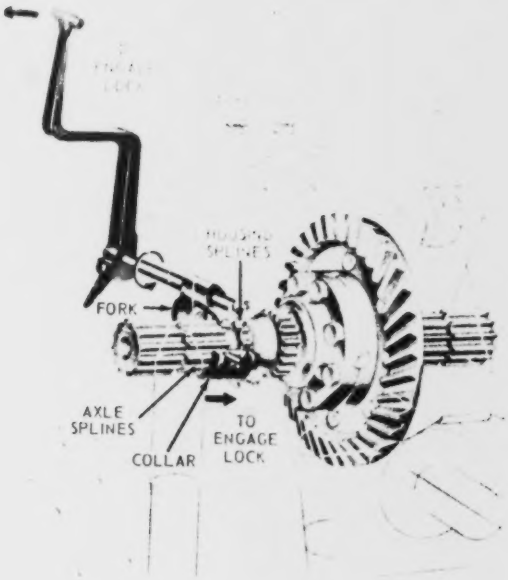
_____

_____

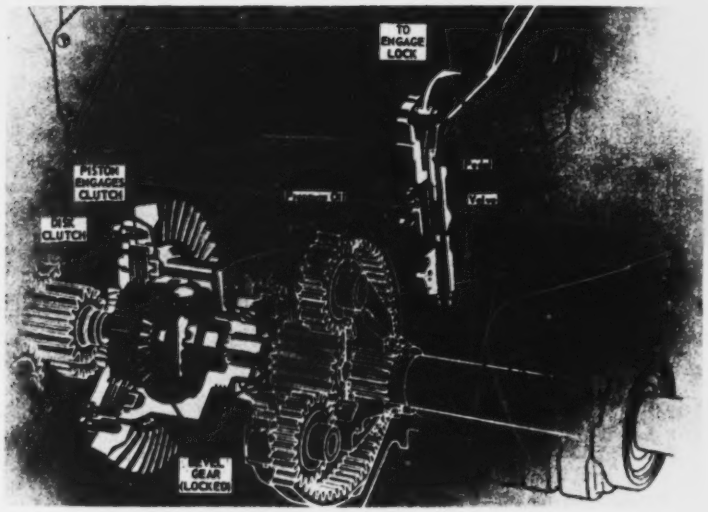
TEST

37. Label the following types of differential locks. Write the correct names in the blanks.


Driven clutch and spider remain locked and travel at same speed.
Spider
Driven clutch elevated by cams disengages from spider clutch teeth and travels at faster speed.
Driven Clutch
Splined Side Gear
Splined Side Gear
Driven Clutch
Spider clutch teeth drive driven clutch.



a. _____ b. _____



c. _____

TEST

38. Describe final drive.

_____

_____

39. Select from the following list major types of final drive systems. Write an "X" in the blank before each correct answer.

_____a. Pinion

_____b. Planetary

_____c. Belt

_____d. Chain

_____e. Power take-off

_____f. Straight axle

40. Distinguish between live axle and dead axle. Write an "L" in the blank pertaining to live axle and a "D" in the blank pertaining to dead axle.

_____a. Only supports machine

_____b. Transmits engine torque as well as supporting part of the machine's weight

41. List types of rear axle bearings.

a. _____

b. _____

c. _____

(NOTE: Test question 42 lists the job sheets. They are an important part of this test. If they have not been completed, check with your instructor.)

42. Demonstrate the ability to

a. Adjust clutch linkage free travel.

b. Remove a clutch assembly.

c. Inspect a clutch assembly.

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TEST

d. Check clutch housing alignment.

e. Install a clutch assembly.

f. Remove and reinstall a standard transmission.

g. Disassemble, inspect, and reassemble a three-speed transmission.

h. Perform a road test for transmission diagnosis.

i. Replace an extension housing bushing and seal.

j. Tune up an automatic transmission.

k. Remove and reinstall a drive (propeller) shaft.

l. Remove and reinstall a cross-and-roller U-joint.

m. Remove and reinstall a ball-and-trunnion U-joint.

n. Balance a drive (propeller) shaft.

o. Check and adjust U-joint angles.

p. Measure backlash between ring gear and drive pinion.

q. Test ring gear and drive pinion gear tooth contact pattern.

r. Install a drive pinion seal.

s. Install a ball-bearing-type axle shaft bearing and seal.

t. Adjust drive pinion bearing preload with carrier assembly removed.

u. Adjust backlash and carrier bearing preload.

v. Remove and reinstall a rear axle housing assembly.

w. Disassemble, inspect, reassemble, and adjust an integral carrier rear axle.

POWER TRAINS
UNIT I

ANSWERS TO TEST

1.	a.	4	i.	8	q.	24	y.	22
	b.	7	j.	3	r.	15	z.	30
	c.	11	k.	10	s.	20	aa.	27
	d.	1	l.	5	t.	17	bb.	29
	e.	9	m.	13	u.	18	cc.	26
	f.	2	n.	14	v.	23	dd.	28
	g.	6	o.	19	w.	16		
	h.	12	p.	25	x.	21		

2. To transfer power from power source to the wheels or tracks

3. Answer should include any two of the following

   a. Connecting and disconnecting power

   b. Selecting speed ratios

   c. Providing a means of reversing

   d. Equalizing power to drive wheels or tracks for turning

4.	a.	4	d.	3
	b.	5	e.	2
	c.	1		

5. a. Fluid

   b. Friction

   c. Gears

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ANSWERS TO TEST

6. Description should include the following — Think of the disc clutch as two discs, each on a separate shaft; when discs are not touching, one can spin very fast without affecting the other; but if they are moved together while one is spinning, the other will also turn, and instantly both shafts will turn as one unit

7. Description should include the following — A system of gears allows the speed of the drive wheels to change in relation to the engine

8. Description should include the following — Set of gears transmits power to the axles and allows each wheel to travel at a different speed and still propel its own load

9.

a.	4	f.	2
b.	1	g.	9
c.	8	h.	5
d.	3	i.	7
e.	6		

10. b, e, g

11.
   a. Flywheel ring (cover)
   b. Release bearing (throwout bearing) and sleeve assembly
   c. Driven rear disc
   d. Intermediate plate
   e. Driven front disc
   f. Pressure plate
   g. Adjusting ring
   h. Release sleeve retainer

12. b

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13.
   a. Hydraulic
   b. Mechanical

ANSWERS TO TEST

14. b, c, d, e, f, g, i

15.

a.	6	e.	2
b.	1	f.	8
c.	5	g.	4
d.	3	h.	7

16. Description should include the following — To provide a method of varying the gear ratio between the engine and rear wheels, and to provide reverse movement

17.

a. Input shaft (clutch shaft)
b. Input shaft bearing retainer
c. Input shaft gear (main drive gear)
d. Second and third gear synchronizer assembly
e. Second speed gear
f. First speed gear
g. First and reverse synchronizer assembly
h. Reverse gear
i. Output shaft (main shaft)
j. Extension housing
k. Reverse idler gear
l. Reverse idler gear shaft
m. Counter or cluster gear
n. Transmission case
o. Countershaft

ANSWERS TO TEST

18. a. Synchromesh
    b. Sliding gear
    c. Collar shift

19. c, d, e, g

20. a. Insert spring (lock ring)
    b. Sleeve
    c. Hub
    d. Inserts
    e. Synchronizer ring

21. Discussion should include the following
    a. Neutral — Input shaft drives cluster gear, which in turn drives constant mesh second and reverse idler gears; no power is transmitted
    b. First gear — First and reverse synchronizer sleeve moves to engage first gear; input shaft transmits power to cluster gear, to first gear, and on to output shaft
    c. Second gear — Second and third gear synchronizer sleeve moves to engage second gear; input shaft transmits power to cluster gear, to second gear, and on to output shaft
    d. Third gear — Second and third gear synchronizer sleeve moves to engage third gear; input shaft transmits power to output shaft
    e. Reverse gear — First and reverse synchronizer sleeve moves to engage reverse idler gear; input shaft transmits power to cluster gear; cluster gear drives reverse idler gear; reverse idler gear drives reverse gear and output shaft in direction opposite engine rotation

22. Description should include the following — A train of gears that can be shifted without interrupting the flow of power, which is controlled by hydraulic clutches

23. Description should include the following
    a. Hydraulic clutches — Control power flow
    b. Gear trains — Transmit power flow

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ANSWERS TO TEST

24. a. Countershaft
    b. Planetary

25. b, c, f

26. a. Lubricates and cools clutches and brakes
    b. Engages clutches and brakes

27. a. Hydrodynamic
    b. Hydrostatic

28. Answer should include any two of the following
    a. Rate of oil flow — Gives the speed
    b. Direction of oil flow — Gives the direction
    c. Pressure of oil — Gives the power

29. Answer should include any three of the following
    a. Provide infinite speeds and torque
    b. Allow smooth shifting without "steps"
    c. Have easy one-lever control
    d. Can be shifted "on the go"
    e. Provide high torque for starting
    f. Have flexible location; no drive lines
    g. Are compact in size for big power
    h. Have no clutches or large gear trains
    i. Reduce shock loads
    j. Require low maintenance and service

ANSWERS TO TEST

30. a. T
    b. H

31. a. T
    b. F

32. a. Oil flow lubricates and cools parts
    b. Oil pressure engages clutches
    c. Oil velocity drives turbines

33. a. Cap
    b. Felt washer
    c. Drive shaft yoke
    d. Grease fitting
    e. Yoke (torque converter end)
    f. Spider and bearing
    g. Dust cap
    h. Pipe plug
    i. Retainer
    j. Lock washer
    k. Cap screw
    l. Yoke (transmission end)
    m. Spider and bearing
    n. Snap ring
    o. Drive shaft tube

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ANSWERS TO TEST

34. a. Rzeppa
    b. Cross-and-roller
    c. Ball-and-trunnion
    d. Constant velocity

35. Answer should include any two of the following
    a. Vibration absorber
    b. Constant velocity U-joint
    c. Torsional vibration damper
    d. Elastomer-sleeved propeller shaft

36. Description should include the following — When one wheel loses resistance on slick ground and starts spinning, the differential lock directs power equally to both wheels by locking the two axles together

37. a. Automatic (no-spin)
    b. Mechanical
    c. Hydraulic

38. Description should include the following — Last phase of the power train; gives final reduction in speed and increase in torque to drive wheels

39. a, b, d, f

40. a. D
    b. L

41. a. Ball
    b. Tapered roller
    c. Flat roller

42. Performance skills evaluated to the satisfaction of the instructor

TRACKS
UNIT II

UNIT OBJECTIVE

After completing this unit, the student should be able to identify parts of a track system, check and adjust track tension, remove and replace tracks on an excavator and crawler tractor, and replace track that has jumped off. The student will show this knowledge by completing the job sheets and unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match terms associated with tracks to their correct definitions.
2. Label basic parts of a track system.
3. Identify the parts of a track section.
4. Identify types of track shoes.
5. Name types of track chains.
6. Match basic parts of a track system to their correct functions.
7. List guidelines for extending track life.
8. List problems that may result from track tension being too tight.
9. List problems that may result from track tension being too loose.
10. Select from a list problems that may result from track misalignment.
11. State how to measure track wear.
12. State how to determine when to turn pins and bushings.
13. Demonstrate the ability to
    a. Check and adjust track tension on an excavator with hydraulic adjusters.
    b. Remove and reinstall track on an excavator with hydraulic adjusters.
    c. Remove and reinstall track on a crawler tractor.
    d. Reinstall track that has jumped off.

TRACKS
UNIT II

SUGGESTED ACTIVITIES

I. Suggested activities

A. Obtain transparency.

(NOTE: Transparency is available from AGC and CIMC.)

B. Gather equipment and materials for job sheet demonstrations.

C. Check with manufacturers and equipment dealers for visual aids to demonstrate track operations.

D. Provide students with objective sheet.

E. Discuss unit and specific objectives.

F. Provide students with information and job sheets.

G. Discuss information sheet.

H. Demonstrate and discuss procedures outlined in job sheets.

I. Give test.

J. Complete appropriate section of competency profiles.

(NOTE: Competency profiles are available from AGC and CIMC.)

II. Instructional materials

A. Objective sheet

B. Suggested activities

C. Information sheet

D. Transparency master: TM #1 — Turning Pins and Bushings

E. Job sheets

1. Job Sheet #1 — Check and Adjust Track Tension on an Excavator with Hydraulic Adjusters

2. Job Sheet #2 — Remove and Reinstall Track on an Excavator with Hydraulic Adjusters

SUGGESTED ACTIVITIES

3. Job Sheet #3 — Remove and Reinstall Track on a Crawler Tractor

4. Job Sheet #4 — Reinstall Track that Has Jumped Off

F. Test

G. Answers to test

III. Unit references

A. *Case 850 Crawler Service Manual 9-72942.* Racine, Wisconsin: JI Case, 1975.

B. *Case 980 Excavator Operators Manual 9-4541.* Racine, Wisconsin: JI Case, n.d.

C. *Fundamentals of Service: Tires and Tracks,* 5th ed. Moline, Illinois: Deere and Company, 1980.

D. Nichols, Herbert L., Jr. *Moving the Earth,* 3rd ed. Greenwich, Connecticut: North Castle Books, 1976.

TRACKS
UNIT II

INFORMATION SHEET

I. Terms and definitions

A. Alignment — Proper positioning or state of adjustment of parts in relation to each other

B. Drift pin — Tapered pin used to align or drive pins and bolts through or out of snug-fitting holes

C. Flotation — Ability to stay on the surface of soft ground or snow

D. Grouser — Ridge or cleat across a track shoe; used to improve traction

E. Misalignment — Not properly aligned

F. Sectional sprocket — Sprocket with a flat wheel containing teeth bolted on in hollow sections

(NOTE: The sectional sprocket provides for easy replacement.)

G. Sprocket (bull wheel) — Driving wheel or gear that meshes with and drives the crawler chain

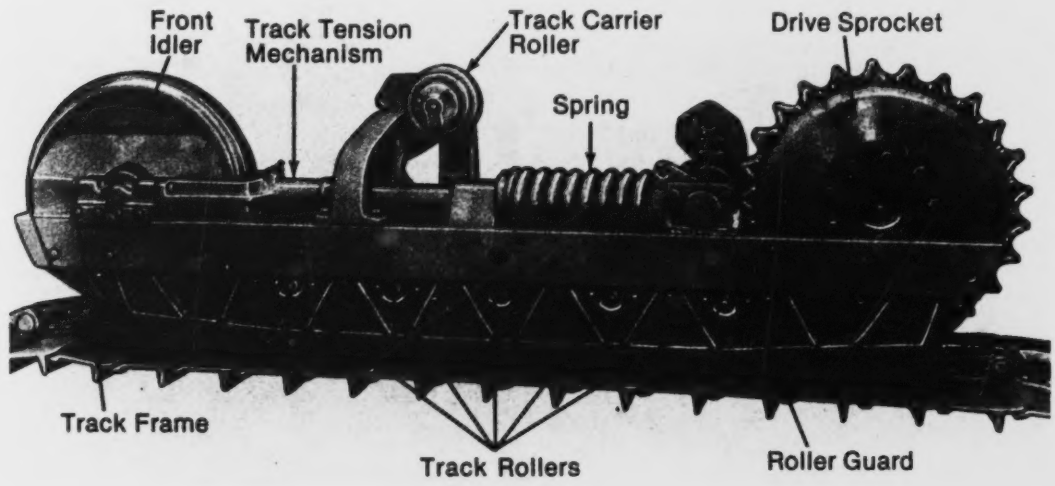
H. Traction — Total amount of driving push of a vehicle on a given surface

INFORMATION SHEET

II. Basic parts of a track system (Figure 1)

(NOTE: The sprocket bull wheel may be a solid wheel or it may be sectioned.)

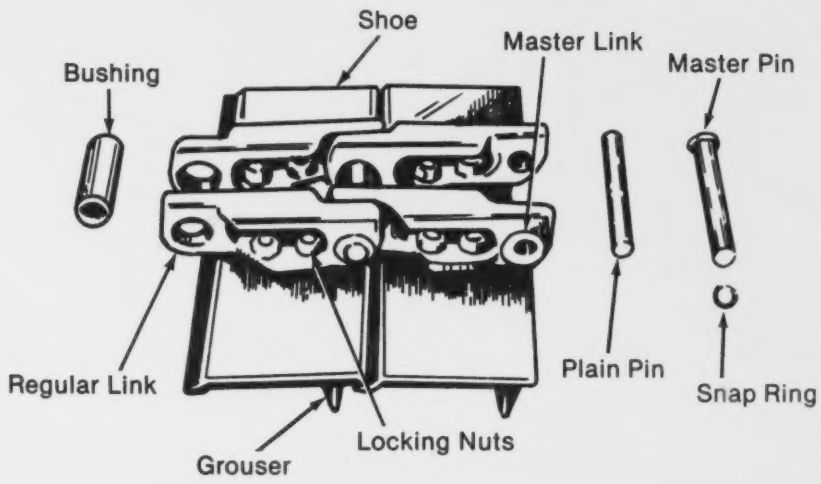
FIGURE 1



Courtesy of Deere and Company, Moline, Illinois.

III. Parts of a track section (Figure 2)

FIGURE 2



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INFORMATION SHEET

IV. Types of track shoes (Figures 3-10)

A. Grouser shoe

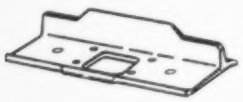
FIGURE 3

B. Cut-out grouser shoe

FIGURE 4

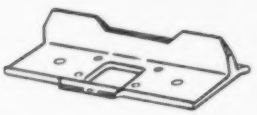
C. Single-caulk snow and ice grouser

FIGURE 5



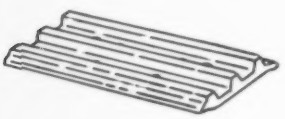
D. Double-caulk snow and ice grouser

FIGURE 6



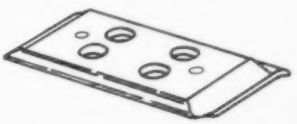
E. Semigrouser shoe

FIGURE 7



F. Flat shoe

FIGURE 8

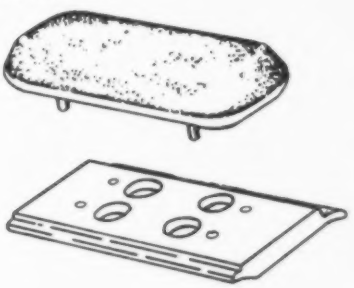


G. Cut-out flat shoe

FIGURE 9

H. Rubber-faced pad adapting shoe and rubber pad

FIGURE 10



INFORMATION SHEET

V. Types of track chains (Figures 11 and 12)

A. Flush

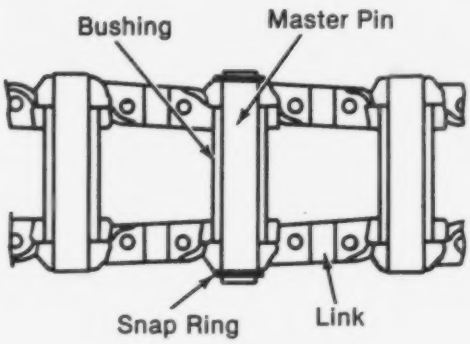
(NOTE: This type of chain has bushings flush with the ends of the links.)

B. Interlocking

(NOTE: This type of chain has bushings extending into the counterbores of the links.)

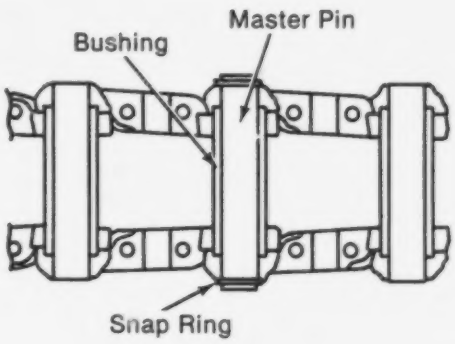
EXAMPLES:

FIGURE 11



Flush-Type Chain

FIGURE 12



Interlocking-Type Chain

Figures 11 and 12 used with permission of Deere and Company, Moline, Illinois.

VI. Functions of basic parts of a track system

A. Front idler — Supports track as it revolves

B. Track tension mechanism — Manually or hydraulically adjusts track tension

C. Spring — Aids operation of track tension mechanism

D. Drive sprocket — Transmits power to track; driven by machine's final drive

E. Roller guards — Protect rollers from obstructions; also help keep track free of dirt and debris

F. Carrier rollers — Support weight of upper portion of track to prevent track from sagging

INFORMATION SHEET

G. Track rollers — Support much of the machine's weight; provide even pressure on track as it revolves and contacts the ground, evenly distributing weight over entire bottom of track to give it greater traction and flotation

H. Track frame — Supports and holds track components in place

VII. Guidelines for extending track life

A. Avoid reckless operation over rough and rocky terrain

B. Do not spin the tracks; apply loads gradually

C. Slow down when traveling over rough terrain

D. Avoid high-speed operation in reverse

E. Stay off concrete and other hard surfaces when possible

F. Keep roller guards in place

G. Clean out packed mud after operating in muddy conditions

H. Check track tension periodically, especially when operating in mud, snow, or sand

I. Do not park on the side of a hill

J. In freezing weather, park on a hard surface to avoid freezing tracks to ground

K. Check torque on all track bolts periodically

L. Inspect track regularly

VIII. Problems that may result from track tension being too tight

A. Loss of drawbar power and speed

B. Drift to right or left

C. Fast wear on pins, bushings, and track links

D. Rapid wear on drive sprockets and idler wheels

E. Extra strain on entire track system because flexibility is lost

F. Unnecessary wear on final drive, drive bearings, and oil seals

G. Abnormal steering clutch wear

INFORMATION SHEET

IX. Problems that may result from track tension being too loose

A. Extremely fast wear on pins, bushings, and track links

B. Unnecessary and rapid wear on sides of drive sprocket, teeth, and idler wheel flanges

C. Damaged or broken drive sprocket, idler, idler bracket, side frames, and rollers

D. Track jumping sprocket in forward or reverse operation

E. Track being thrown off when tractor is turned

F. Noisy track

G. Frequent accumulation of trash in track

X. Problems that may result from track misalignment

A. Drift from direct course

B. Abnormal wear on idler wheel flanges and front idler flanges

C. Excessive track, link, and drive sprocket wear

D. Rapid steering, clutch, and brake wear

E. Operator annoyance and fatigue caused by constantly steering tractor to prevent it from drifting

XI. How to measure track wear

A. Use measuring tools such as ruler, tape, depth gauge, or calipers to measure track; then compare measurements to manufacturer's specifications

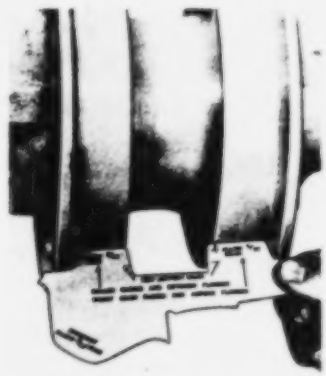
INFORMATION SHEET

B. Use special wear gauges supplied by manufacturers as a rough guide for track wear (Figure 13)

(NOTE: These gauges are not precise, but they do indicate whether the part is somewhat worn or worn beyond the wear limits.)

EXAMPLE:

FIGURE 13



Courtesy of Deere and Company, Moline, Illinois.

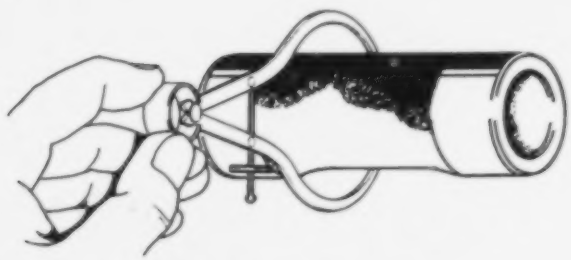
XII. Determining when to turn pins and bushings (Transparency #1)

A. External, calipers

1. Use calipers to measure center of bushing (Figure 14)
2. Compare measurement with outer edge of bushing
3. If wear is over 0.120 inch, turn bushing 180 degrees

EXAMPLE:

FIGURE 14



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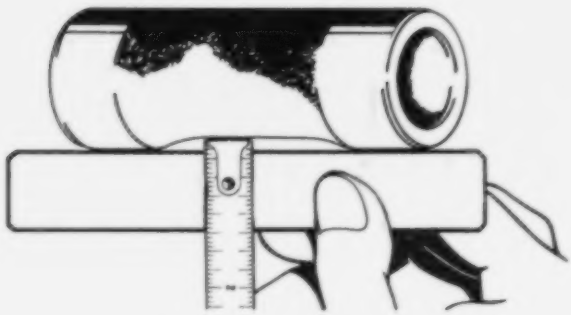
INFORMATION SHEET

B. External, straightedge

1. Use straightedge along length of bushing (Figure 15)
2. Measure in to center of bushing from straightedge
3. If wear is over 0.120 inch, turn bushing

EXAMPLE:

FIGURE 15



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INFORMATION SHEET

C. Internal

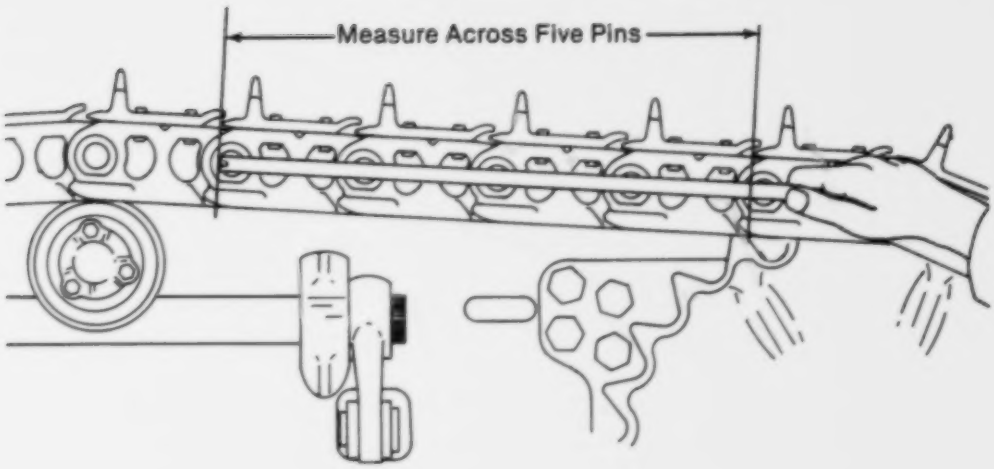
1. Pull track tight and measure across four track links (five pins) (Figure 16)

2. If measurement is more than 25 ½ inches, bushing wear is in excess of 0.120 inch, and bushings need to be turned

(NOTE: The master pin should not be included in this measurement. Pins and bushings must be turned before bushings crack or wear through. Never allow them to be run until they are destroyed; this would damage other parts of the track.)

EXAMPLE:

FIGURE 16



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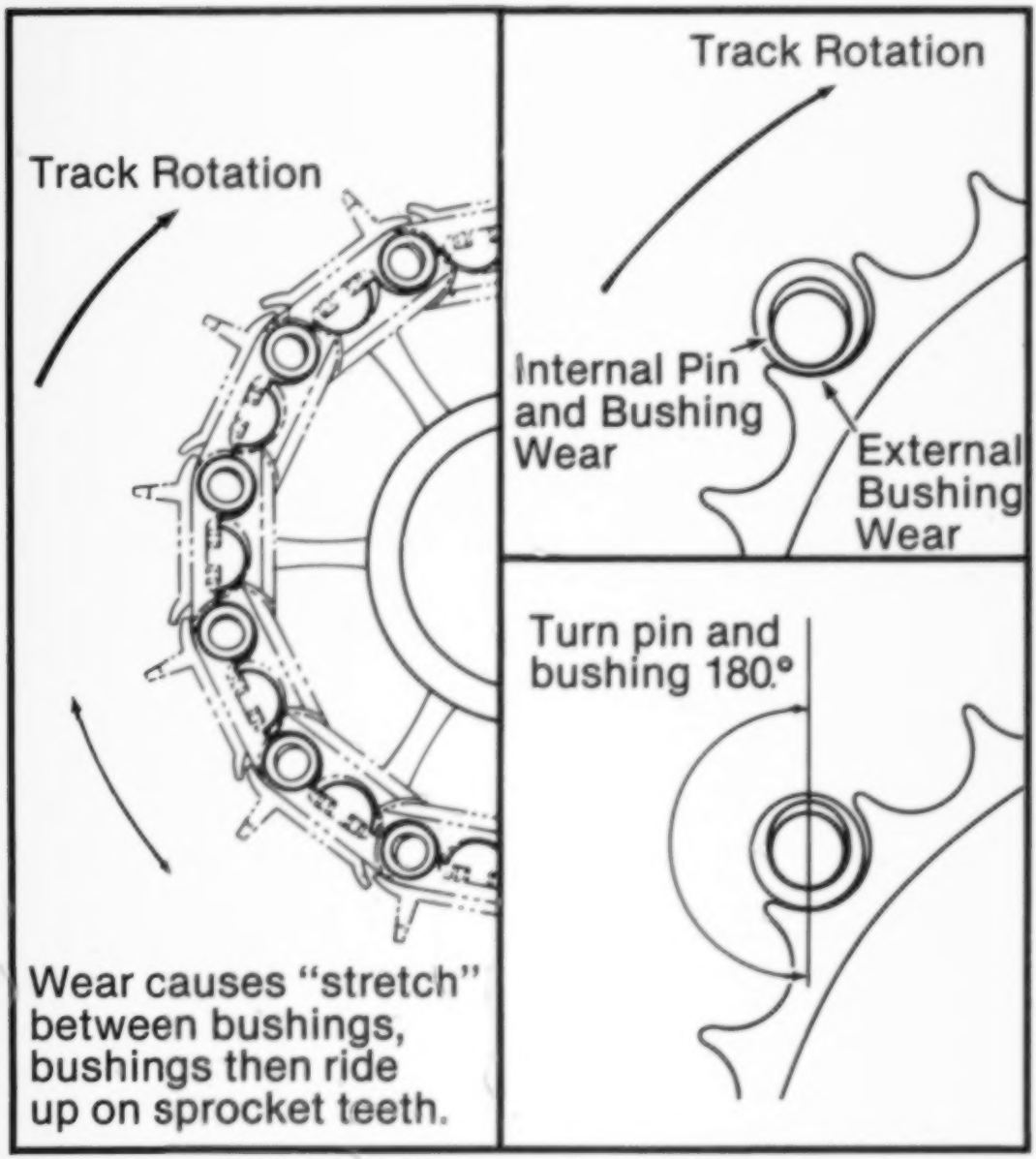
Turning Pins and Bushings


Track Rotation
Track Rotation
Internal Pin and Bushing Wear
External Bushing Wear
Turn pin and bushing 180°
Wear causes "stretch" between bushings, bushings then ride up on sprocket teeth.

Used with permission of J I Case, a Tenneco Company.

TRACKS
UNIT II

JOB SHEET #1 — CHECK AND ADJUST TRACK TENSION ON AN EXCAVATOR WITH HYDRAULIC ADJUSTERS

I. Equipment and materials

A. Excavator with hydraulic adjusters

B. Basic tool kit

C. Rule

D. Grease gun

E. Grease

F. Shop towels

II. Procedure

A. Check track tension

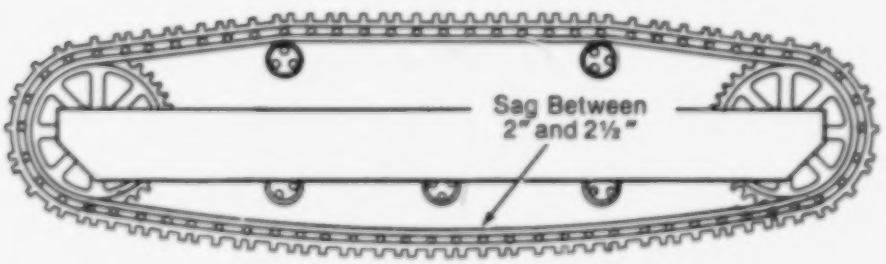
1. Position excavator on a hard, level surface

2. Swing boom to side; power down with boom to lift one track off ground

3. Measure sag in center portion of track

(NOTE: Sag should be 2 to 2 ½ inches. See Figure 17.)

FIGURE 17



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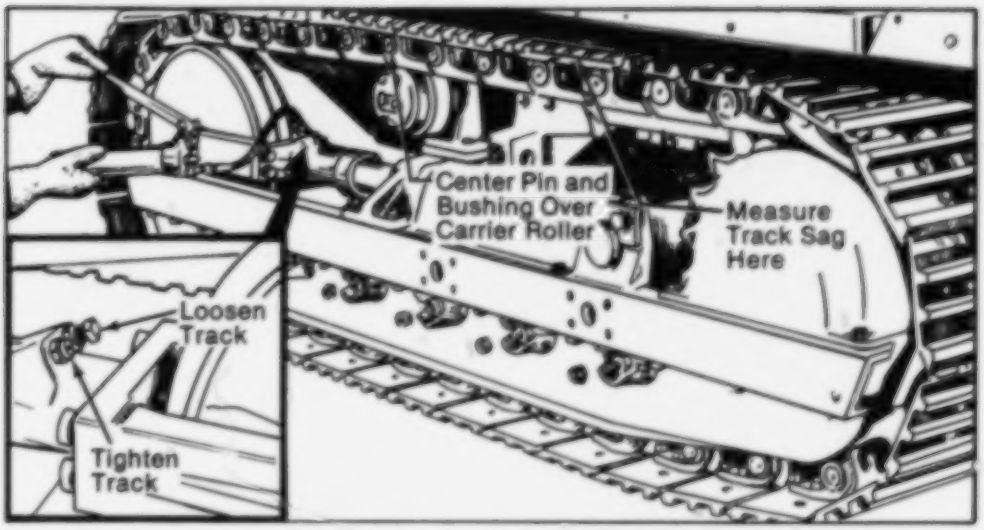
4. Follow same procedure to check other track

JOB SHEET #1

B. Tighten tension on track (Figure 18)

FIGURE 18



Adapted with permission of Deere and Company, Moline, Illinois.

1. Use grease gun to apply grease through fitting
2. Apply grease to adjustment cylinder until track is adjusted to correct tension

C. Loosen tension on track

1. Use wrench to loosen grease fitting
2. Back fitting off three or four full turns to let grease out of cylinder until track is adjusted to correct tension
3. Retighten grease fitting

D. Follow same procedure on other track

E. Return track to ground

F. Park excavator on a level area

G. Clean work area; clean and put away all tools and equipment

TRACKS
UNIT II

JOB SHEET #2 — REMOVE AND REINSTALL TRACK ON AN EXCAVATOR WITH HYDRAULIC ADJUSTERS

I. Equipment and materials

A. Excavator with hydraulic adjusters

B. Basic tool kit

C. Drift pin

D. Heavy hammer

E. Heavy pry bar

F. Heavy-duty jack

G. Hoist or winch

H. Grease gun and grease

I. Gloves

J. Safety glasses

K. Shop towels

L. Appropriate service manual

II. Procedure for removing track

A. Position excavator on a hard, level surface so that track master pin is halfway up sprocket

(NOTE: Allow enough room in front of the crawler for the track to roll completely out.)

B. Set parking brake

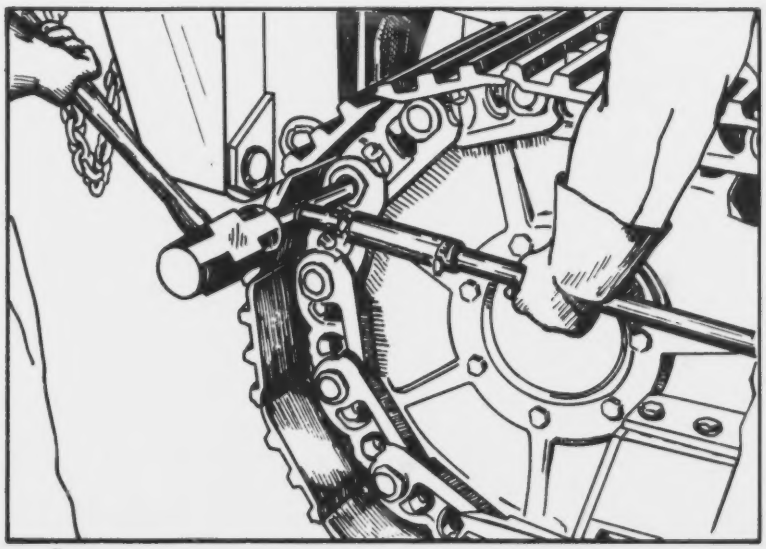
C. Loosen fittings on track adjusters to allow grease to run out until track is loose

(CAUTION: To eliminate all excess tension on track cylinder, be sure that machine is sitting on the ground before loosening grease fittings.)

D. Remove snap ring

E. Use drift pin and heavy hammer to drive out master pin (Figure 19)

FIGURE 19



Adapted with permission of J I Case, a Tenneco Company.

F. Place a heavy pry bar through a track link; pull lower end of track free of sprocket

G. Have another person start engine, and engage sprocket for the track being removed; turn wheel forward very slowly until entire track is free of sprocket

(CAUTION: Use extreme caution when handling track. Never place fingers between track shoes when removing track.)

H. Use the heavy bar to carry track over the carrier rollers and idler until it is lying flat on the ground

(NOTE: When the track is started, it will roll flat from its own weight.)

III. Procedure for reinstalling track

A. Use heavy-duty jack to jack up track frame

B. Lay out track beneath rollers with open end of track toward rear of tractor

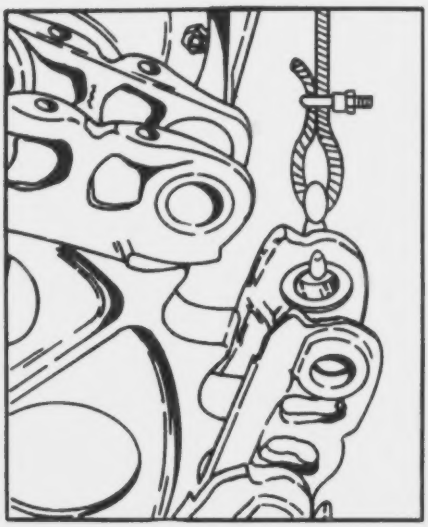
JOB SHEET #2

C. Lower excavator onto track, positioning unit so that drive sprocket is close to end of track

D. Pull track halfway up onto sprocket; block with a brace

E. Attach hoist or winch to front of track (Figure 20)

FIGURE 20



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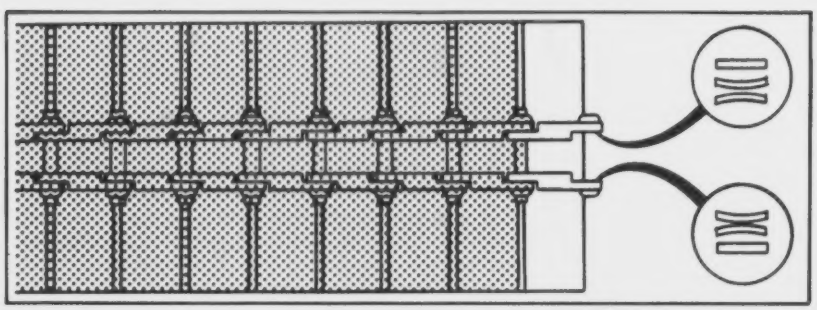
F. Pull track up and over the idler and carrier rollers, and onto sprocket

G. Draw track ends together to within 1 inch (Figure 21)

FIGURE 21



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JOB SHEET #2

H. Install the four cone-shaped seals and two spacers (chamfer edge in) into master links

(NOTE: Each set of master links requires four seals and two spacers.)

I. Drive track together until the spacers and seals are held in place by the links

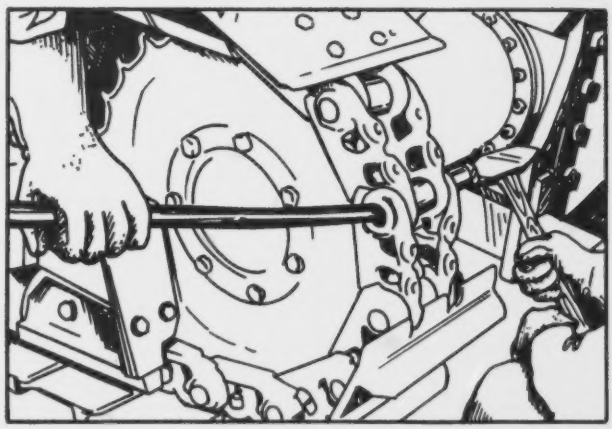
J. Use heavy bar to align links

K. Grease bushings and master pin

L. Drive pin into links with heavy hammer (Figure 22)

(CAUTION: Be sure to wear safety glasses while driving pin.)

FIGURE 22



M. Adjust track for proper tension (Job Sheet #1)

N. Clean work area; clean and put away all tools and equipment

TRACKS
UNIT II

JOB SHEET #3 — REMOVE AND REINSTALL TRACK ON A CRAWLER TRACTOR

I. Equipment and materials

- A. Basic tool kit
- B. Heavy-duty floor jack
- C. Hoist
- D. Wood blocks
- E. Chain hoist or winch
- F. Heavy, soft hammer
- G. Heavy pry bar
- H. Shims
- I. Gloves
- J. Safety glasses
- K. Shop towels
- L. Appropriate service manual
- M. Crawler tractor

II. Procedure for removing track

- A. Position tractor on a hard, level surface
- B. Place a floor jack securely under front cross bar

  (NOTE: Some manufacturers recommend alternate points for raising. Check service manual.)

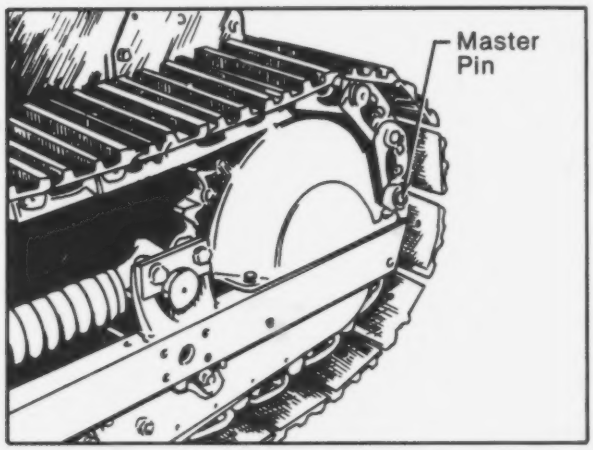
- C. Raise jack until one track is raised off ground
- D. Start engine; shift transmission into first gear
- E. Pull back on steering lever that controls track still on ground

JOB SHEET #3

F. Engage clutch so that raised track moves until master pin has moved around drive sprocket to about 6 inches from floor (Figure 23)

(CAUTION: Do not let the machine move, and be sure that rotating track is clear of ground.)

FIGURE 23



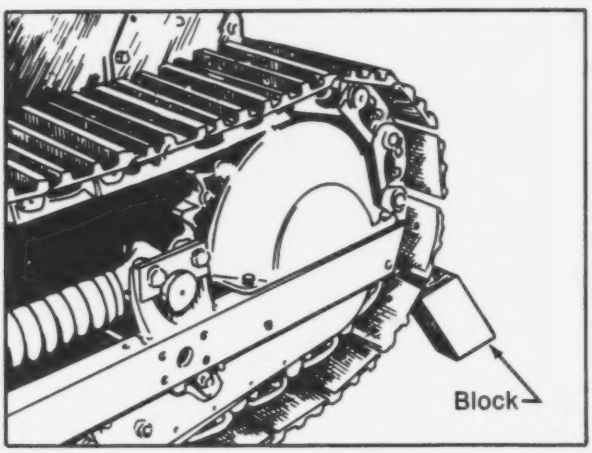
Adapted with permission of Deere and Company, Moline, Illinois.

G. Release all tension from track to be removed

H. Place blocks under track near drive sprocket (Figure 24)

(NOTE: This will loosen track for easier separation.)

FIGURE 24

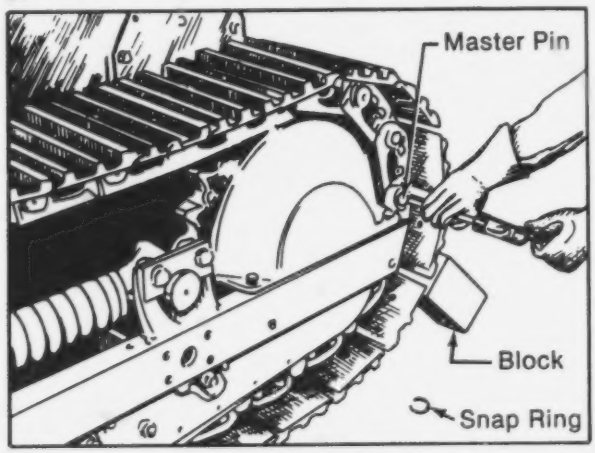


Adapted with permission of Deere and Company, Moline, Illinois.

JOB SHEET #3

I. Remove snap ring, and drive out master pin (Figure 25)

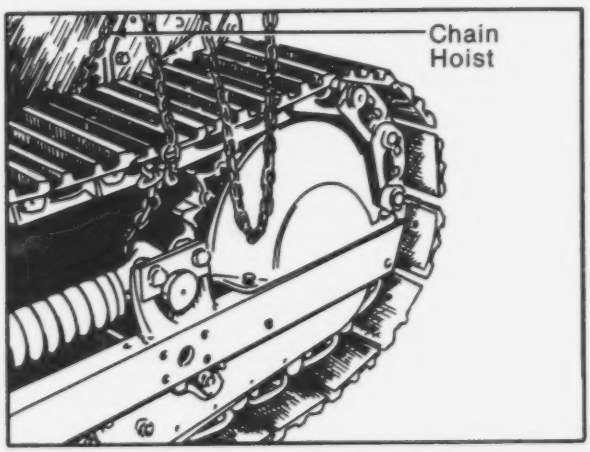
FIGURE 25



Adapted with permission of Deere and Company, Moline, Illinois.

J. Use chain hoist to pull track up and toward front of machine (Figure 26)

FIGURE 26



Adapted with permission of Deere and Company, Moline, Illinois.

JOB SHEET #3

K. Continue pulling until track is clear of drive sprocket

(CAUTION: Keep hands and feet away from track during separation.)

L. Lay track flat on ground

M. Remove track from area

N. Follow same procedure if other track is to be removed

III. Procedure for reinstalling track

A. Place track on ground under track rollers

(NOTE: Be sure that track is placed correctly. Rear end of track should be about in line with rear of drive sprocket.)

B. Use hoist to pull track up over front idler and rear sprocket

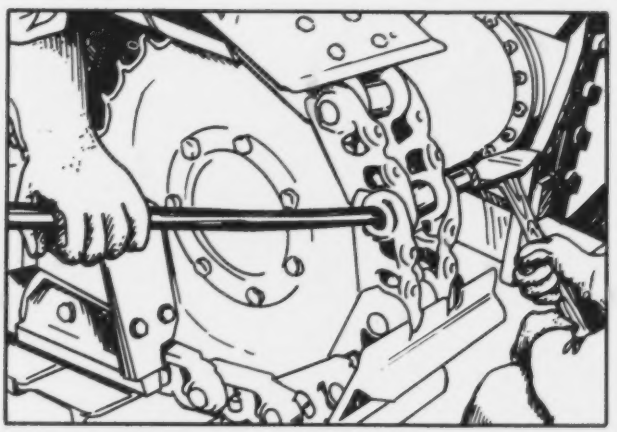
C. To take out sag, place a wood block between upper part of carrier and track

D. Use pry bar in master pin hole to pull ends of track together

E. Line up holes by driving onto links with a soft hammer

F. Position master pin; drive into place (Figure 27)

FIGURE 27



JOB SHEET #3

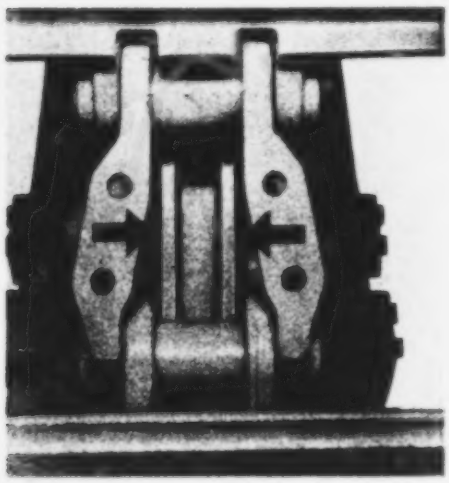
G. Install snap ring

H. Align track

1. Examine position of track links in relation to front idler flanges (Figure 28)

(NOTE: If clearance is not equal on both sides, adjustment is required.)

FIGURE 28



Adapted with permission of Deere and Company, Moline, Illinois.

JOB SHEET #3

2. Adjust by removing or adding idler adjustment shims (Figure 29)

   (NOTE: Shims may have to be removed or added from one side or the other if wear is on both sides of idler.)

FIGURE 29

Adapted with permission of Deere and Company, Moline, Illinois.

3. Drive machine forward on level ground about 100 feet

4. Stop machine without touching steering levers

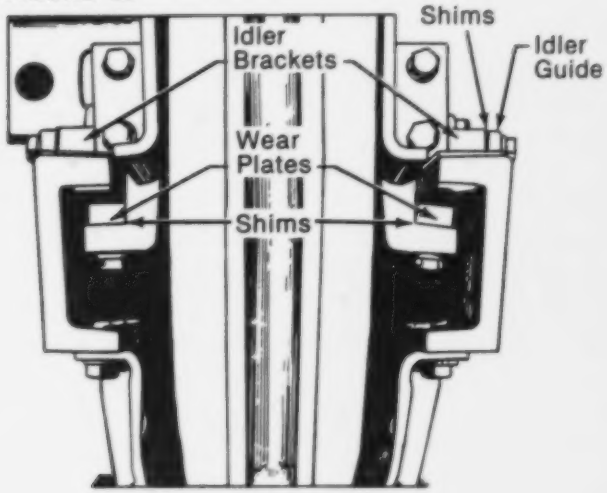
5. Examine position of track lines in relation to front idler flanges

JOB SHEET #3

6. If the idler is worn on one side, remove or add shims on each side of idler bracket (Figure 30)

   (NOTE: If alignment cannot be achieved by removing or adding shims, check for a bent frame.)

FIGURE 30



Adapted with permission of Deere and Company, Moline, Illinois.

7. Remove or add shims on each side of the idler to correct vertical misalignment

   (NOTE: These shims will be found between underside of the frame and idler bracket, and between top side of frame and idler bracket. See Figure 29.)

8. Check track frame for twists or bends if alignment of any components becomes too difficult

I. Adjust tension on tracks (Job Sheet #1)

J. Clean work area; clean and put away all tools and equipment

TRACKS
UNIT II

JOB SHEET #4 — REINSTALL TRACK THAT HAS JUMPED OFF

I. Equipment and materials

- A. Tracked vehicle
- B. Tool kit
- C. Heavy wood blocks
- D. Heavy pry bar
- E. Safety glasses
- F. Gloves
- G. Appropriate service manual

II. Procedure for track off sprocket

- A. Place block between track and sprocket
- B. Back machine while turning
- C. Turn so that machine is forced against track
- D. It may be necessary to try several times before track jumps back on sprocket
- E. Remove block
- F. Adjust track tension (Job Sheet #1)

III. Procedure for track off to inside at front idler

- A. Loosen track slightly
- B. Work machine backward and forward until track engages idler
- C. Adjust track tension (Job Sheet #1)

IV. Procedure for track off to outside at front idler

- A. Loosen track slightly
- B. Use heavy bar to pry track as machine is moved very slowly

(NOTE: Sometimes it is possible to use a dozer to help push track back in place.)

C. Adjust track tension (Job Sheet #1)

V. Procedure for track off at bottom rollers

A. Back machine up on a block

B. Work track back in place

C. Adjust track tension (Job Sheet #1)

TRACKS
UNIT II

TEST

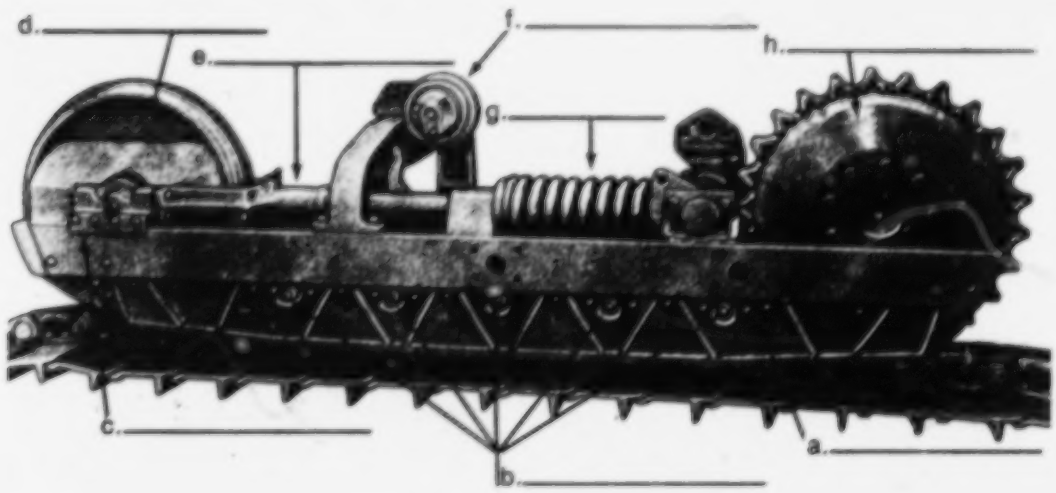
NAME _____ SCORE _____

1. Match terms associated with tracks to their correct definitions. Write the correct numbers in the blanks.

_____a.	Ridge or cleat across a track shoe; used to improve traction	1. Sprocket (bull wheel)
_____b.	Total amount of driving push of a vehicle on a given surface	2. Sectional sprocket
_____c.	Driving wheel or gear that meshes with and drives the crawler chain	3. Alignment
_____d.	Ability to stay on the surface of soft ground or snow	4. Traction
_____e.	Sprocket with a flat wheel containing teeth bolted on in hollow sections	5. Misalignment
_____f.	Not properly aligned	6. Grouser
_____g.	Tapered pin used to align or drive pins and bolts through or out of snug-fitting holes	7. Drift pin
_____h.	Proper positioning or state of adjustment of parts in relation to each other	8. Flotation

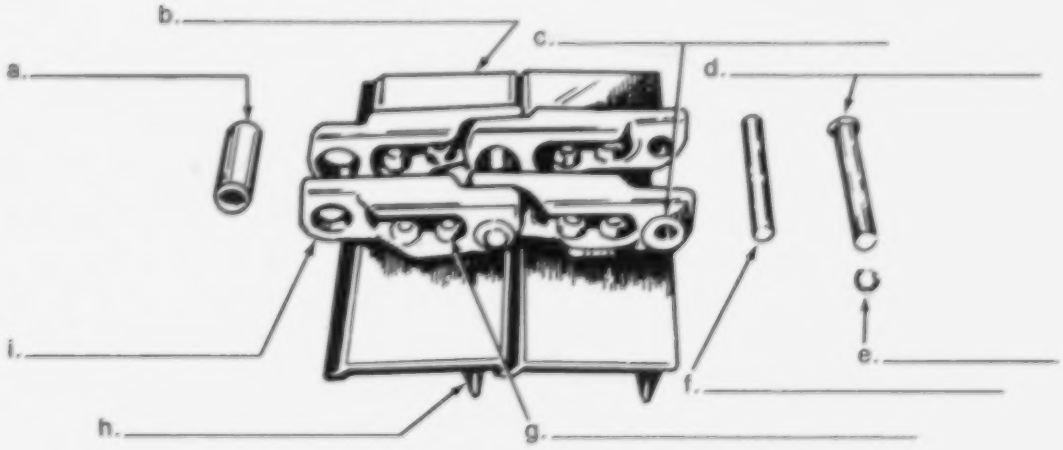
TEST

2. Label basic parts of the track system illustrated below



3. Identify the parts of the track section illustrated below. Write the correct names in the blanks.

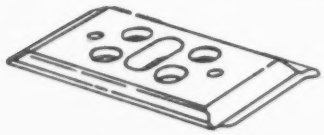
Bushing	**Master pin**	**Locking nuts**
Shoe	**Snap ring**	**Regular link**
Master link	**Plain pin**	**Grouser**



TEST

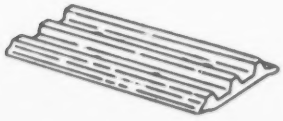
4. Identify the following types of track shoes. Write the correct names in the blanks.

Grouser shoe
Flat shoe
Cut-out flat shoe
Cut-out grouser shoe
Semigrouser shoe
Rubber-faced pad adapting shoe and rubber pad
Single-caulk snow and ice grouser
Double-caulk snow and ice grouser

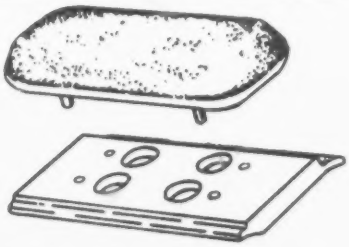


a. _____

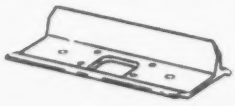
b. _____



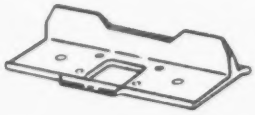
c. _____



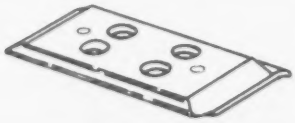
d. _____



e. _____



f. _____



g. _____

h. _____

5. Name types of track chains.

a. _____

b. _____

TEST

6. Match basic parts of a track system to their correct functions. Write the correct numbers in the blanks.

_____a.	Aids operation of track tension mechanism	1. Front idler
_____b.	Protect rollers from obstructions; also help keep track free of dirt and debris	2. Roller guards
_____c.	Supports track as it revolves	3. Spring
_____d.	Support weight of upper portion of track to prevent track from sagging	4. Carrier rollers
_____e.	Supports and holds track components in place	5. Track frame
_____f.	Manually or hydraulically adjusts track tension	6. Track tension mechanism
_____g.	Transmits power to track; driven by machine's final drive	7. Track rollers
_____h.	Support much of the machine's weight; provide even pressure on track as it revolves and contacts the ground, evenly distributing weight over entire bottom of track to give it greater traction and flotation	8. Drive sprocket

7. List eight guidelines for extending track life.

a. _____

_____

b. _____

_____

c. _____

_____

d. _____

_____

e. _____

_____

TEST

f. _____

_____

g. _____

_____

h. _____

_____

8. List four problems that may result from track tension being too tight.

a. _____

b. _____

c. _____

d. _____

9. List four problems that may result from track tension being too loose.

a. _____

b. _____

c. _____

d. _____

10. Select from the following list problems that may result from track misalignment. Write an "X" in the blank before each correct answer.

_____a. Excessive track, link, and drive sprocket wear

_____b. Rapid steering, clutch, and brake wear

_____c. Rapid tire and track wear

_____d. Abnormal wear on idler wheel flanges and front idler flanges

_____e. Drift from direct course

_____f. Operator annoyance and fatigue caused by constant engine noise

TEST

11. State how to measure track wear.

a. _____

_____

_____

b. _____

_____

_____

12. State how to determine when to turn pins and bushings.

a. External, calipers

1) _____

2) _____

3) _____

b. External, straightedge

1) _____

2) _____

3) _____

c. Internal

1) _____

2) _____

(NOTE: Test question 13 lists the job sheets. They are an important part of this test. If they have not been completed, check with your instructor.)

13. Demonstrate the ability to

a. Check and adjust track tension on an excavator with hydraulic adjusters.

b. Remove and reinstall track on an excavator with hydraulic adjusters.

c. Remove and reinstall track on a crawler tractor.

d. Reinstall track that has jumped off.

TRACKS
UNIT II

ANSWERS TO TEST

1.

a.	6	e.	2
b.	4	f.	5
c.	1	g.	7
d.	8	h.	3

2.

a.	Roller guard	e.	Track tension mechanism
b.	Track rollers	f.	Track carrier roller
c.	Track frame	g.	Spring
d.	Front idler	h.	Drive sprocket

3.

a.	Bushing	f.	Plain pin
b.	Shoe	g.	Locking nuts
c.	Master link	h.	Grouser
d.	Master pin	i.	Regular link
e.	Snap ring		

4.

a. Cut-out flat shoe

b. Single-caulk snow and ice grouser

c. Semigrouser shoe

d. Rubber-faced pad adapting shoe and rubber pad

e. Cut-out grouser shoe

f. Double-caulk snow and ice grouser

g. Flat shoe

h. Grouser shoe

ANSWERS TO TEST

5. a. Flush

   b. Interlocking

6. a. 3 e. 5

   b. 2 f. 6

   c. 1 g. 8

   d. 4 h. 7

7. Answer should include any eight of the following

   a. Avoid reckless operation over rough and rocky terrain

   b. Do not spin the tracks; apply loads gradually

   c. Slow down when traveling over rough terrain

   d. Avoid high-speed operation in reverse

   e. Stay off concrete and other hard surfaces when possible

   f. Keep roller guards in place

   g. Clean out packed mud after operating in muddy conditions

   h. Check track tension periodically, especially when operating in mud, snow, or sand

   i. Do not park on the side of a hill

   j. In freezing weather, park on a hard surface to avoid freezing tracks to ground

   k. Check torque on all track bolts periodically

   l. Inspect track regularly

8. Answer should include any four of the following

   a. Loss of drawbar power and speed

   b. Drift to right or left

   c. Fast wear on pins, bushings, and track links

ANSWERS TO TEST

d. Rapid wear on drive sprockets and idler wheels

e. Extra strain on entire track system because flexibility is lost

f. Unnecessary wear on final drive, drive bearings, and oil seals

g. Abnormal steering clutch wear

9. Answer should include any four of the following

a. Extremely fast wear on pins, bushings, and track links

b. Unnecessary and rapid wear on sides of drive sprocket, teeth, and idler wheel flanges

c. Damaged or broken drive sprocket, idler, idler bracket, side frame, and rollers

d. Track jumping sprocket in forward or reverse operation

e. Track being thrown off when tractor is turned

f. Noisy track

g. Frequent accumulation of trash in track

10. a, b, d, e

11. Answer should include the following

a. Use measuring tools such as ruler, tape, depth gauge, or calipers to measure track; then compare measurements to manufacturer's specifications

b. Use special wear gauges supplied by manufacturers as a rough guide for track wear

12. Answer should include the following

a. External, calipers

1) Use calipers to measure center of bushing

2) Compare measurement with outer edge of bushing

3) If wear is over 0.120 inch, turn bushing 180 degrees

ANSWERS TO TEST

b. External, straightedge

1) Use straightedge along length of bushing

2) Measure in to center of bushing from straightedge

3) If wear is over 0.120 inch, turn bushing

c. Internal

1) Pull track tight and measure across four track links (five pins)

2) If measurement is more than 25 ½ inches, bushing wear is in excess of 0.120 inch, and bushings need to be turned

13. Performance skills evaluated to the satisfaction of the instructor

DECK MACHINERY
UNIT III

UNIT OBJECTIVE

After completing this unit, the student should be able to identify basic parts of a deck layout and of a propel power train. The student should also be able to adjust and repair various units of the deck machinery. The student will show this knowledge by completing job sheets and unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match terms associated with deck machinery to their correct definitions.
2. Identify basic parts of a deck layout.
3. Name structural divisions of an excavator.
4. Describe the three sets of power trains on an excavator.
5. Distinguish between an A-frame and a gantry.
6. List types of deck mountings and travel units.
7. List types of rotating supports (swing rollers).
8. Identify basic parts of a propel power train.
9. Demonstrate the ability to
    a. Test control valves for speed and direction.
    b. Remove swing motor from hydraulic excavator.
    c. Disassemble swing brake, replace brake shoes, and reassemble swing brake.
    d. Remove excavator undercarriage; replace swing gear, bearing, seals, gasket; and reassemble excavator.

DECK MACHINERY
UNIT III

SUGGESTED ACTIVITIES

I. Suggested activities

A. Obtain transparencies.

(NOTE: Transparencies are available from AGC and CIMC.)

B. Provide students with objective sheet.

C. Discuss unit and specific objectives.

D. Provide students with information and job sheets.

E. Discuss information sheet.

F. Demonstrate and discuss procedures outlined in job sheets.

G. Give test.

H. Complete appropriate section of competency profiles.

(NOTE: Competency profiles are available from AGC and CIMC.)

II. Instructional materials

A. Objective sheet

B. Suggested activities

C. Information sheet

D. Transparency masters

1. TM #1 — Power Trains
2. TM #2 — A-Frame and Gantry
3. TM #3 — Turntable and Swing Unit
4. TM #4 — Rotating Supports (Swing Rollers)

E. Job sheets

1. Job Sheet #1 — Test Control Valves for Speed and Direction
2. Job Sheet #2 — Remove Swing Motor from Hydraulic Excavator

SUGGESTED ACTIVITIES

3. Job Sheet #3 — Disassemble Swing Brake, Replace Brake Shoes, and Reassemble Swing Brake

4. Job Sheet #4 — Remove Excavator Undercarriage; Replace Swing Gear, Bearing, Seals, Gasket; and Reassemble Excavator

F. Test

G. Answers to test

III. Unit references

A. Nichols, Herbert L., Jr. *Moving the Earth,* 3rd ed. Greenwich, Connecticut: North Castle Books, 1976.

B. *Service Manual 235 Excavator.* Peoria, Illinois: Caterpillar Tractor Co., 1980.

DECK MACHINERY
UNIT III

INFORMATION SHEET

I. Terms and definitions

A. Sheave — Grooved wheel or pulley

B. Turntable — Base that supports a part and allows it to rotate or swing

C. Pinion gear — Smallest of a train of gears or the smaller of two meshing gears

D. Bull gear — Toothed driving wheel that is the largest or strongest in the mechanism

E. Swing motor — Hydraulic-type motor used to operate the swing or rotating unit of a machine

F. Eyebolt — Bolt that has a looped or round head

G. ± — Symbol for plus or minus tolerance

H. psi — Pounds per square inch

I. Shim — Thin piece of material used in a space for adjustment of fit

J. Pintle — Vertical pin connected at the bottom to another part; serves as a center of rotation

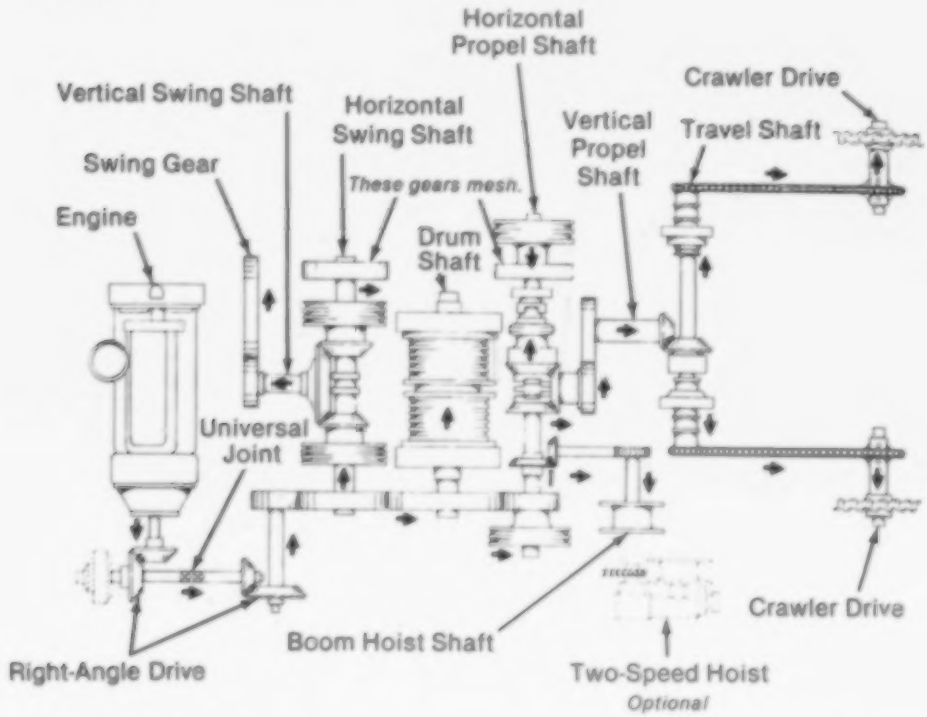
K. Deck machinery — Equipment and machinery that are installed on the deck of a vehicle

INFORMATION SHEET

II. Basic parts of a deck layout (Figure 1)

(NOTE: The operator's cab is also located on the deck.)

FIGURE 1



Source: Gar Wood Industries, Inc.

III. Structural divisions of an excavator

A. Top or revolving unit (superstructure)

B. Mounting or travel unit

C. Various attachments

IV. Three sets of power trains on an excavator (Transparency #1)

A. Hoist — Deck-mounted drums that control in/out and up/down movement of bucket

INFORMATION SHEET

B. Swing — Upper unit supported by rollers or bolts on a turntable, which rotates deck and swings boom in either direction

C. Propel — Unit that provides means to walk or propel the vehicle

V. A-frame and gantry (Transparency #2)

A. A-frame — Steel structure on machinery deck with cross bar slightly above cab roof; carries sheaves for boom support line

B. Gantry — Steel structure on machinery deck projecting high above cab roof; supports boom cables on large equipment

(NOTE: The gantry and some A-frames will fold or collapse so that they can be lowered for shorter booms or for traveling under low obstructions.)

VI. Types of deck mountings and travel units (Figures 2-5)

A. Crawler

EXAMPLES:

FIGURE 2

FIGURE 3

INFORMATION SHEET

B. Truck

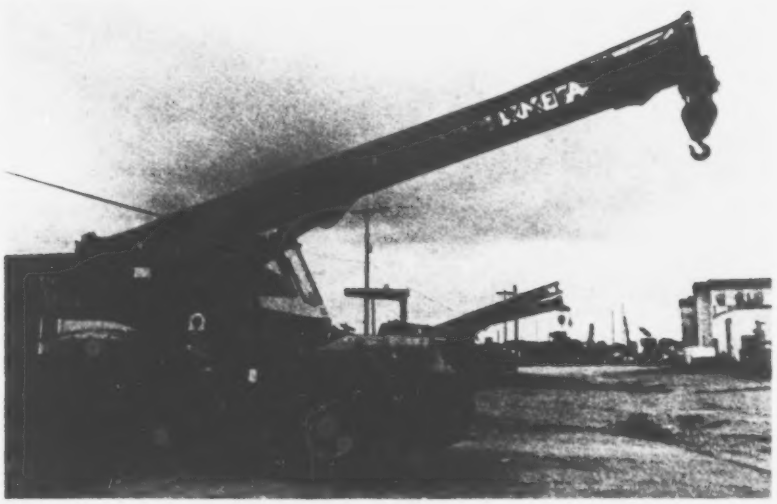
EXAMPLE:

FIGURE 4

C. Rubber-wheeled, self-propelled

EXAMPLE:

FIGURE 5



(NOTE: In some units, the upper unit is supported by rollers or balls on a circular track or turntable welded to the frame and is rotated by a vertical pinion gear that meshes with bull gear teeth in the turntable. See Transparency #3.)

INFORMATION SHEET

VII. Types of rotating supports (swing rollers) (Transparency #4)

(NOTE: All the weight of the revolving unit and attachment rests on rollers; below are some of the types that are used.)

A. Swing rollers between two tracks

(NOTE: Rollers running between tracks help to keep the deck from tipping.)

B. Swing and hook rollers

(NOTE: In this type, the rollers carry the load only, and the hook rollers stabilize the machine.)

C. Bearing-type swing rollers

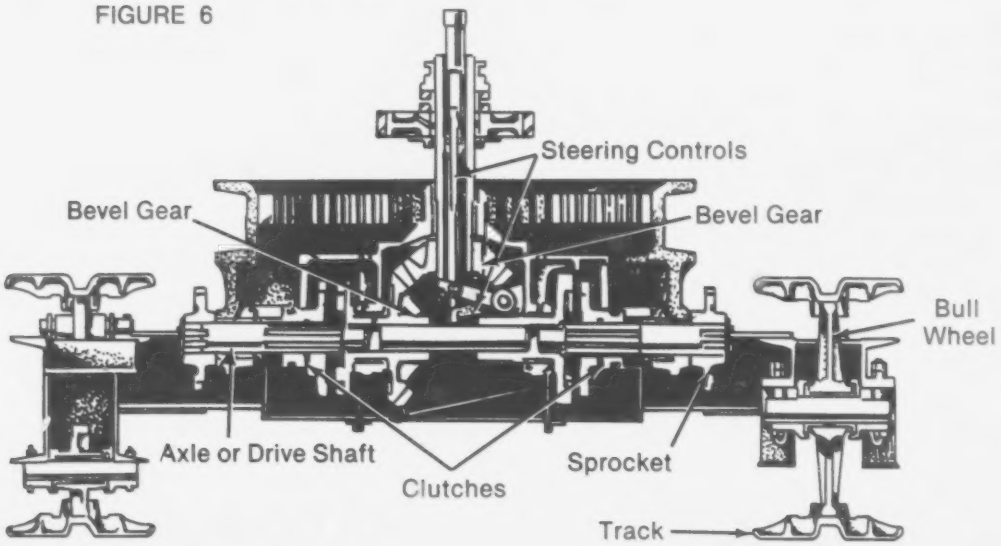
(NOTE: These rollers move between a lower and upper track; the unit is stabilized by hook rollers, the race flanges, and the center shaft.)

D. Ball race

(NOTE: This construction uses races forged in one piece. It is stronger than a two-piece race and permits more accurate machining and less overall height than other constructions.)

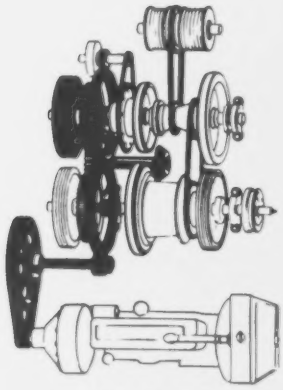
VIII. Basic parts of a propel power train (Figure 6)

FIGURE 6

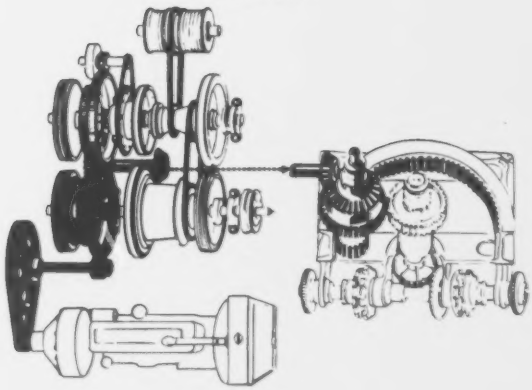


Used with permission of Bucyrus-Erie Company, South Milwaukee, Wisconsin.

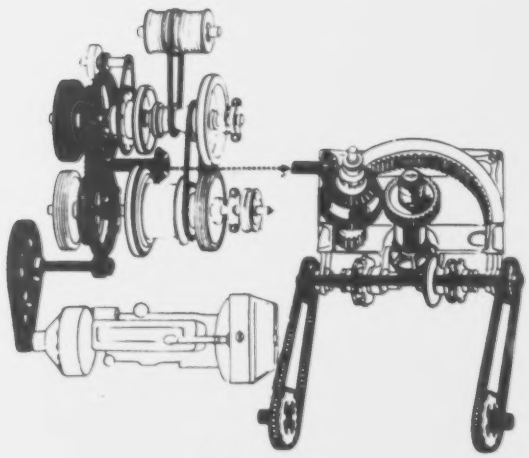
Power Trains



Hoist



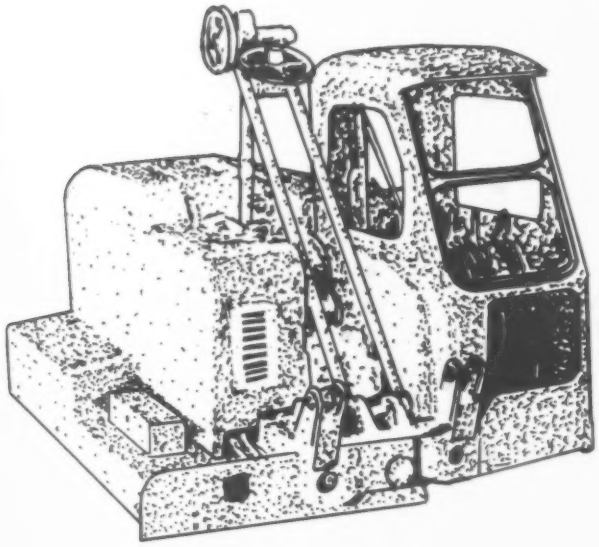
Swing



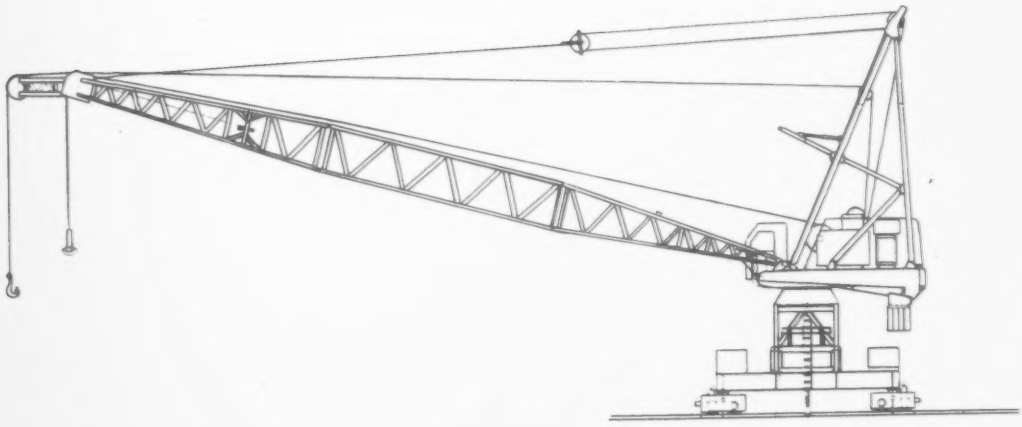
Propel

Adapted with permission of Bucyrus — Erie Company, South Milwaukee, Wisconsin.

A-Frame and Gantry



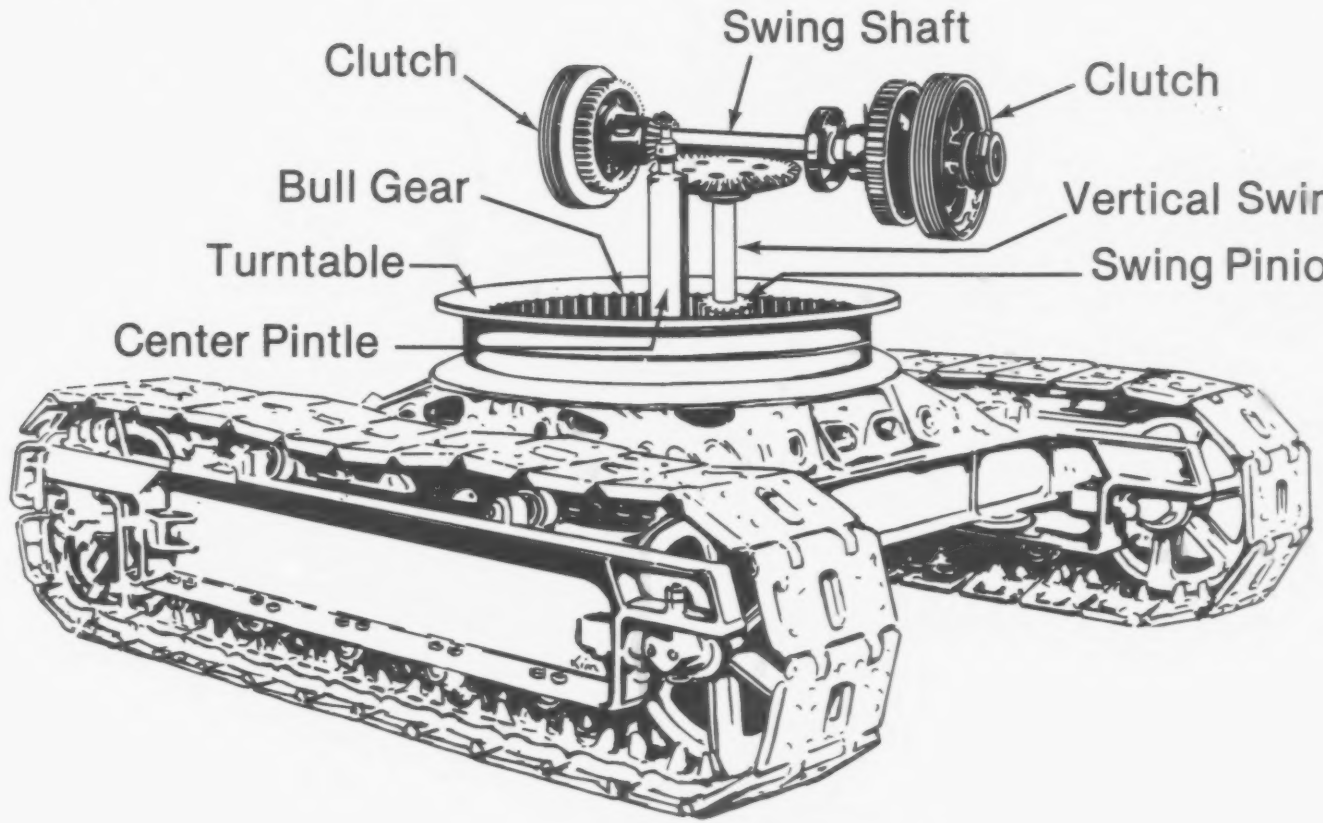
A-Frame



Gantry

1618

Turntable and Swing Unit



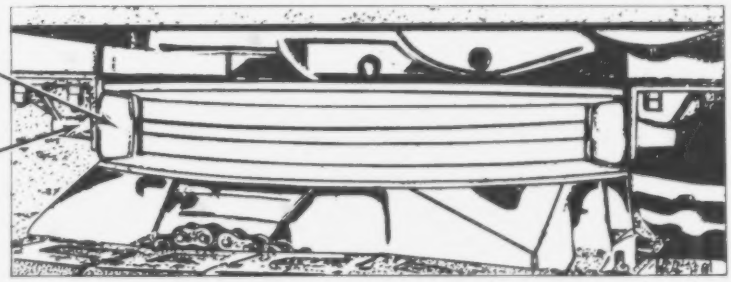
1619

1620

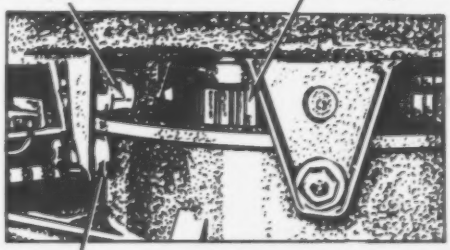
TM #3

HEM - 265-E

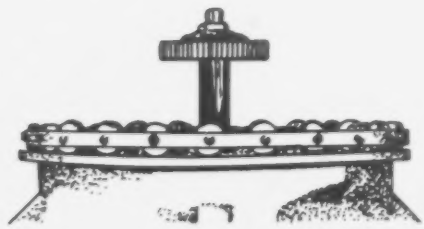
Rotating Supports (Swing Rollers)



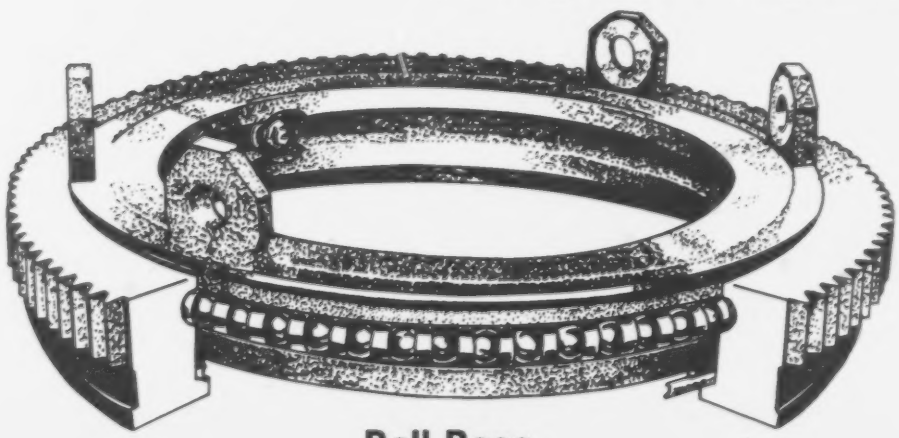
Swing Rollers Between Tracks



Swing and Hook Rollers



Bearing-Type Swing Rollers



Ball Race

Top figure — Used with permission of Bucyrus-Erie Company, South Milwaukee, Wisconsin. Middle figures — Used with permission of Harnischfeger Corporation, Milwaukee, Wisconsin. Bottom figure — Source: Thew Shovel Company.

DECK MACHINERY
UNIT III

JOB SHEET #1 — TEST CONTROL VALVES FOR SPEED AND DIRECTION

I. Equipment and materials

A. Basic hand-tool set

B. Pressure gauges

C. Shims (0.005 inch)

D. Shop towels

II. Procedure

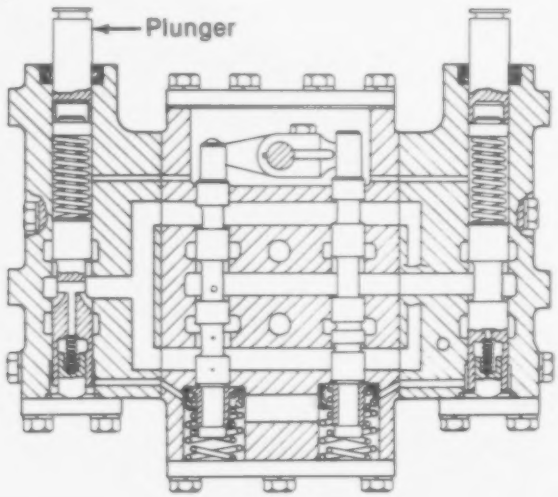
A. Screw in plunger on track brake until brake valve spool is blocked

B. Install pressure gauges in covers on ends of stems of main control valves for track movement

C. Start engine and let idle

D. Push valve plunger on left side down 5/16 inch (Figure 7)

FIGURE 7



E. Check pressure

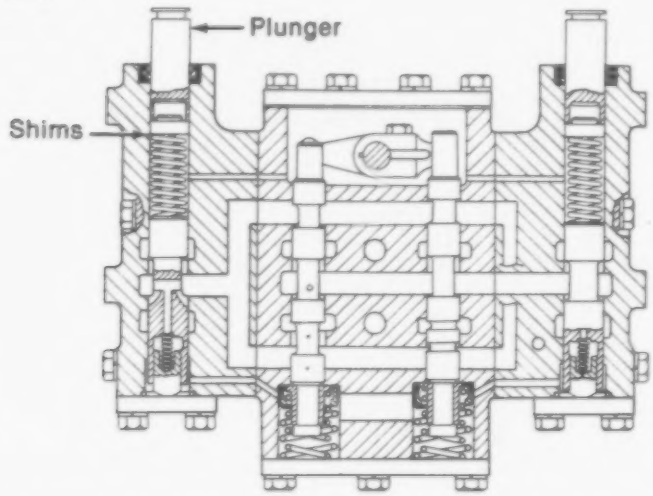
(NOTE: Pressure at the inner end of the control valve stem for right track and outer end of control valve stem for left track movement must be 175 ± 4.0 psi.)

JOB SHEET #1

F. If pressures are not the same, check oil lines to control lines for restriction

G. If pilot pressure to the control valves is less than 171 psi or more than 179 psi, make adjustment by adding shims to increase pressure or removing shims to decrease pressure (Figure 8)

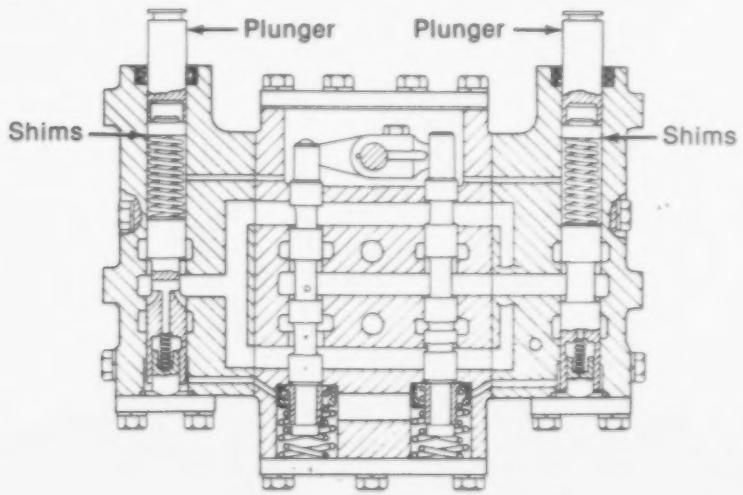
FIGURE 8



(NOTE: When plunger is pushed down to its full travel, oil pressure to the control valve must be 335 ± 25 psi.)

H. Push valve plunger on right side down 5/16 inch (Figure 9)

FIGURE 9



JOB SHEET #1

I. Check pressure

J. Adjust oil pressure by using shims (Figure 9)

(NOTE: Add shims to increase pressure,or remove shims to decrease pressure.)

K. Clean work area; clean and put away all tools and equipment

DECK MACHINERY
UNIT III

JOB SHEET #2 — REMOVE SWING MOTOR FROM HYDRAULIC EXCAVATOR

I. Equipment and materials

A. Basic hand-tool set

B. Two ½" x 13 NC forged eyebolts

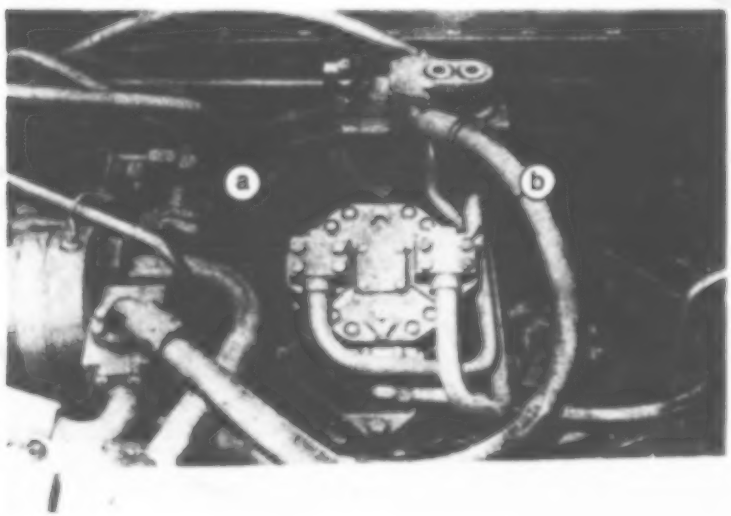
C. Hoist

D. Shop towels

II. Procedure

A. Remove lines (a) and (b) from swing motor (Figure 10)

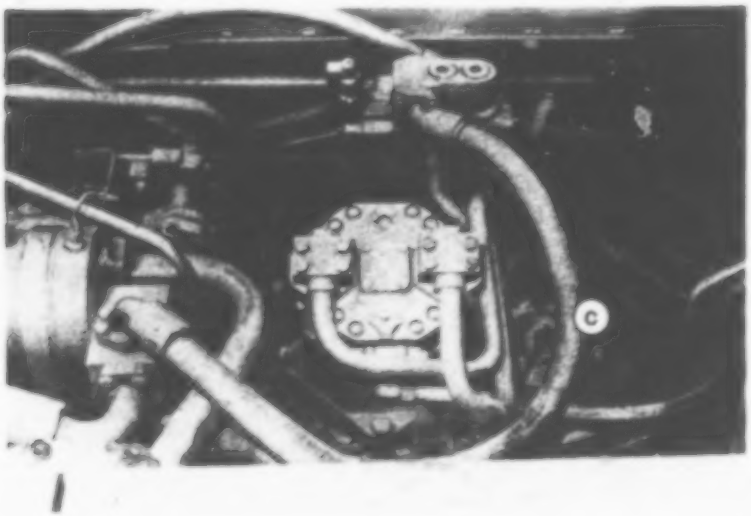
FIGURE 10



JOB SHEET #2

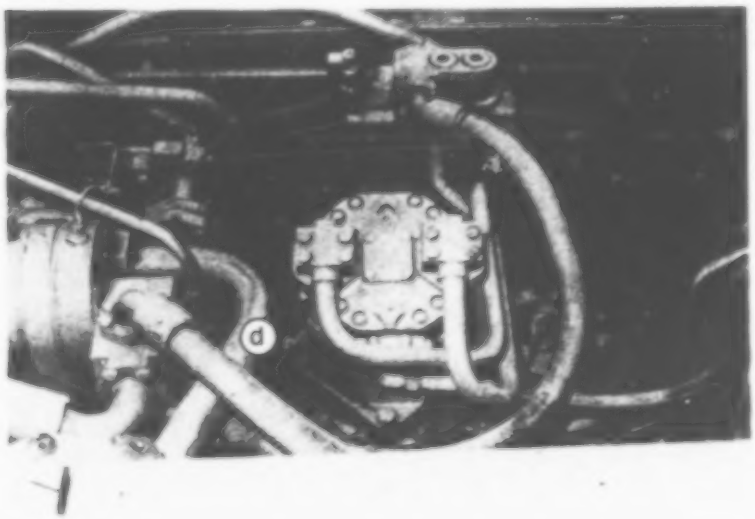
B. Disconnect drain line (c) from swing motor (Figure 11)

FIGURE 11



C. Remove the four hold-down bolts (d) from motor (Figure 12)

FIGURE 12



JOB SHEET #2

D. Install two eyebolts on swing motor (Figure 13)

FIGURE 13

E. Connect chain to eyebolts and connect hoist to sling (Figure 14)

FIGURE 14

JOB SHEET #2

F. Raise hoist gently until motor is free and clear

G. Push left plunger down to its full travel

H. Move steering control hand lever to the left one-half the distance of its full travel

I. Check pressure

(NOTE: Pressure of the oil at both ends of the valve for left track movement must be 335 psi. Pressure of the pilot oil on the inner end of the valve for right track movement must be 335 psi; pressure at the outer end must be zero.)

J. Move steering control hand lever its full travel to left

K. Check pressure

(NOTE: Pressure of the oil to outer end of stem for left track movement and pressure of oil at inner end of stem of control valve for right track movement must be approximately 335 psi.)

L. Push right plunger down to its full travel

M. Move steering control hand lever to the right one-half the distance of its full travel

N. Check pressure

(NOTE: Pressure of the pilot oil at the inner end of the valve for left track movement must be 335 psi, and pressure at the outer end must be zero.)

O. Move steering control hand lever its full travel to right

P. Check pressure

(NOTE: Pressure at both ends of the valve for right track movement will be zero.)

Q. Unscrew plunger in track brake valve until brake valve spool operates normally

R. Clean work area; clean and put away all tools and equipment

DECK MACHINERY
UNIT III

JOB SHEET #3 — DISASSEMBLE SWING BRAKE, REPLACE BRAKE SHOES, AND REASSEMBLE SWING BRAKE

I. Equipment and materials

A. Basic hand-tool set

B. Brake tools

C. New set of brake shoes and springs

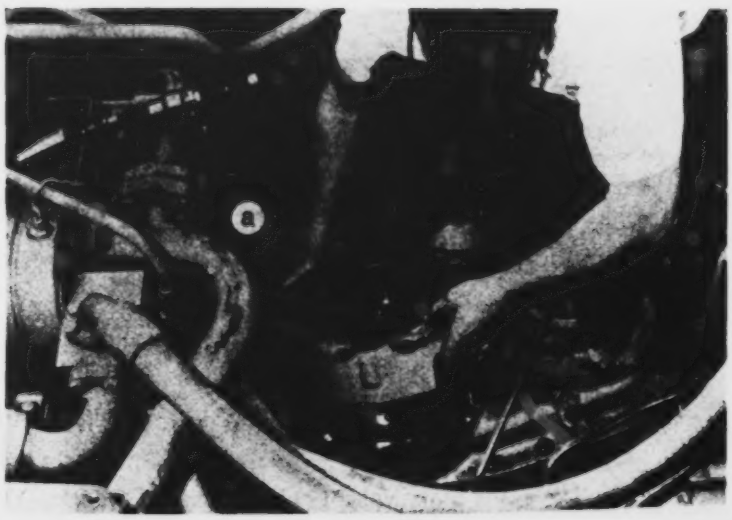
II. Procedure

A. Remove swing motor (Job Sheet #2)

B. Remove bolts from swing brake housing

C. Remove swing brake housing (a) (Figure 15)

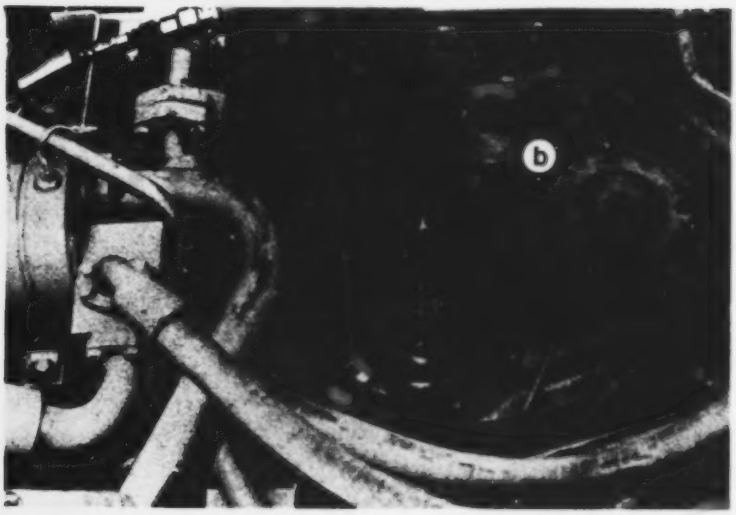
FIGURE 15



JOB SHEET #3

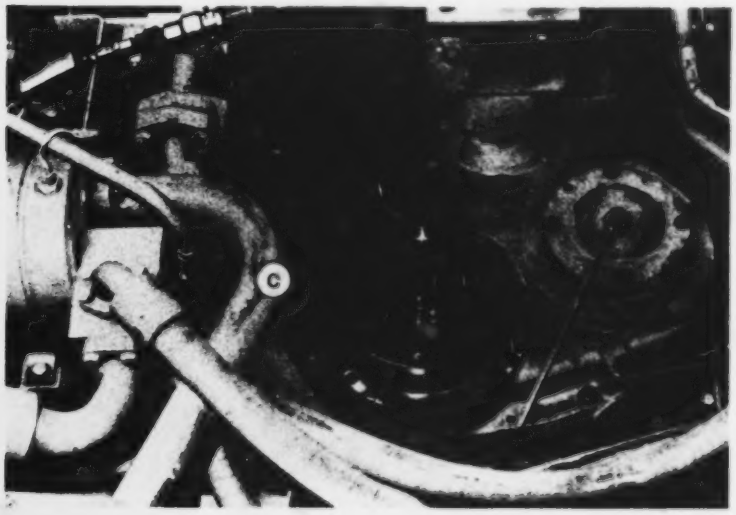
D. Remove brake drum (b) (Figure 16)

FIGURE 16



E. Disconnect brake linkage from lever (c) (Figure 17)

FIGURE 17

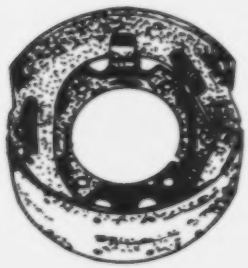


JOB SHEET #3

F. Remove bolts that hold plate to bearing cage

G. Remove plate, linings, and lever as a unit (Figure 18)

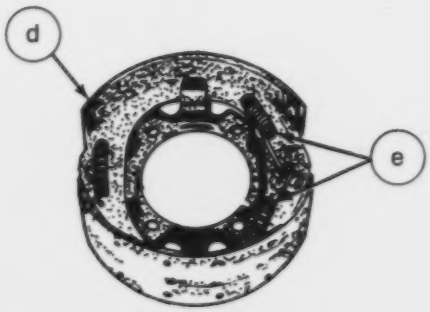
FIGURE 18



H. Remove springs and lining from plate

I. Install new linings (d) and springs (e) on plate (Figure 19)

FIGURE 19



JOB SHEET #3

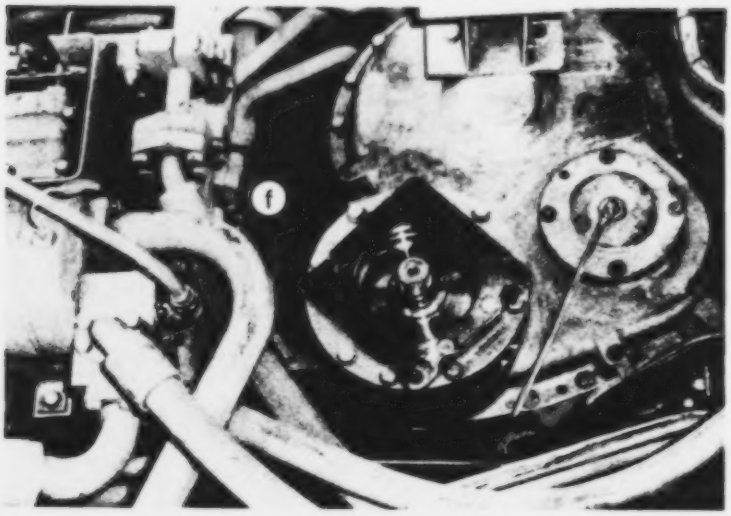
J. Put lever in position and install plate and lining unit

K. Reinstall bolts that hold plate to bearing cage

L. Install brake drum

M. Connect brake linkage to lever (f) (Figure 20)

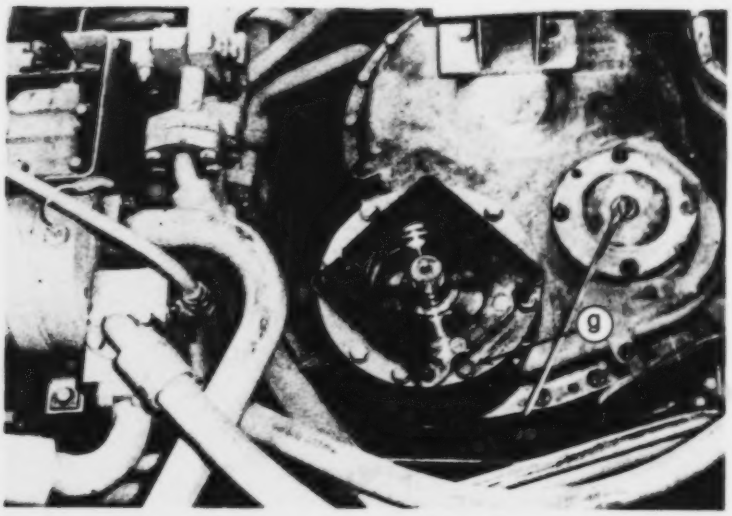
FIGURE 20



N. Install swing brake housing

O. Reinstall housing bolts (g) (Figure 21)

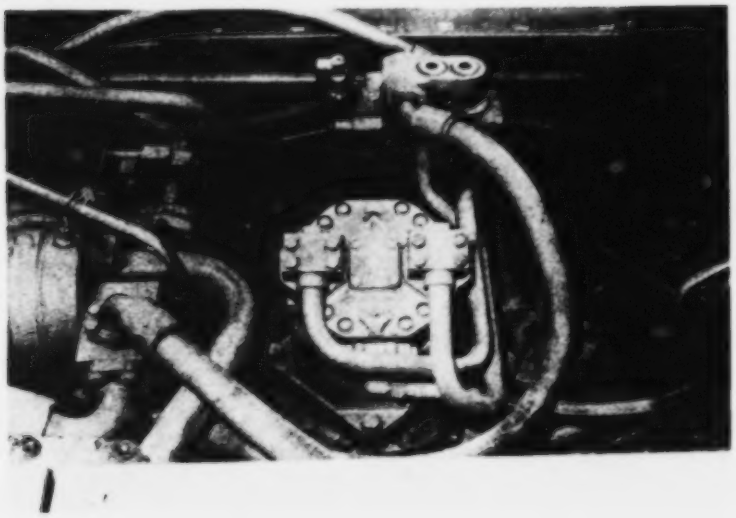
FIGURE 21



JOB SHEET #3

P. Reinstall swing motor (Figure 22)

FIGURE 22



Q. Clean work area; clean and put away all tools and equipment

DECK MACHINERY
UNIT III

JOB SHEET #4 — REMOVE EXCAVATOR UNDERCARRIAGE; REPLACE SWING GEAR, BEARING, SEALS, GASKET; AND REASSEMBLE EXCAVATOR

I. Equipment and materials

A. Tool kit

B. 6 heavy-duty jacks

(NOTE: Sometimes it is more practical to use a crane for lifting upper structure.)

C. Three-legged sling

D. Loader or other heavy piece of equipment

E. Torque wrench

F. Braces and blocking plates

G. 3 lifting brackets

H. Three 3/4" x 6" bolts

I. Two 1" x 9 NC guide bolts

J. Swing gear bearing unit and seal

(NOTE: Swing gear bearing and seal are usually manufactured as one unit and are replaced as one unit.)

K. New seal and gasket

L. Liquid gasket material

M. Grease (type recommended by manufacturer)

N. Contact cement

O. Hoist

II. Procedure for removing undercarriage

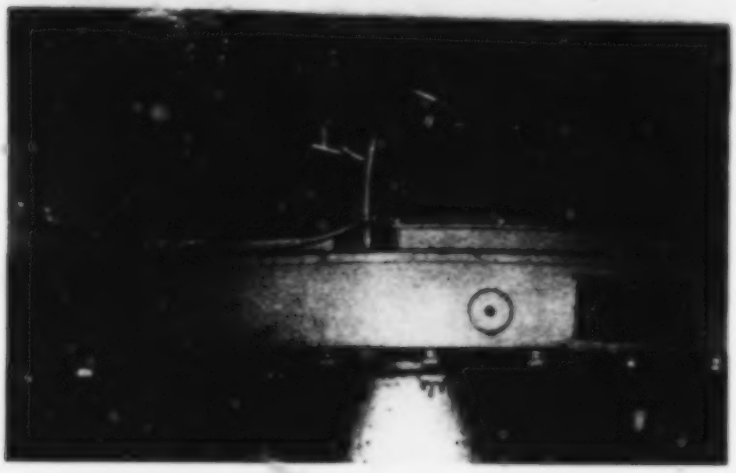
A. Move machine to a level, hard surface area

B. Remove dust cover from swing gear

C. Drain oil from swing gear oil pan

D. Remove grease tube between upper frame and swing gear (Figure 23)

FIGURE 23



E. Turn upper structure 90 degrees to undercarriage

F. Put a mark on swing gear on each side of the two swing lock brackets (Figure 24)

FIGURE 24

JOB SHEET #4

G. Turn upper structure back to straight position

H. Remove bolts between marks that hold swing gear to upper frame

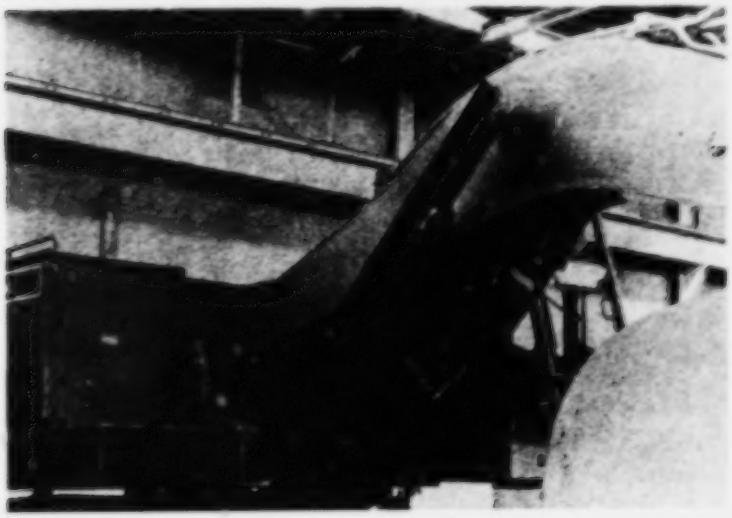
I. Turn upper structure back to 90-degree position

(NOTE: Be sure that stick and bucket are folded under the boom.)

J. Release oil pressure in boom circuit

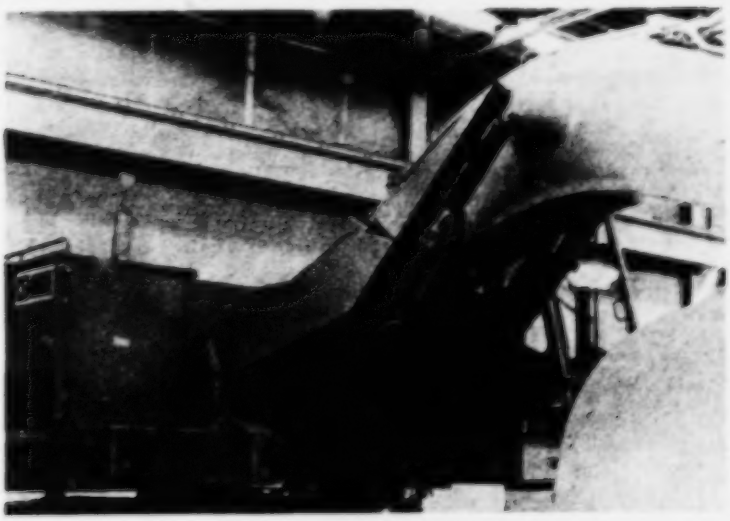
K. Install blocking plates in lines of boom cylinders (Figure 25)

FIGURE 25



L. Install braces on boom cylinders (Figure 26)

FIGURE 26

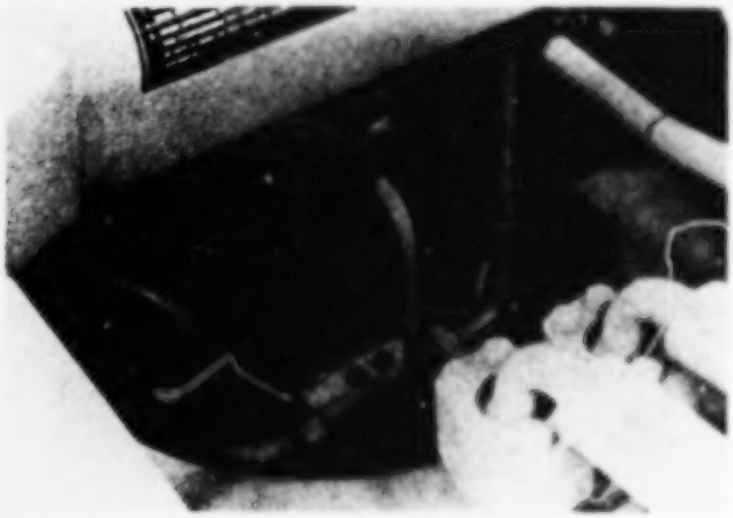


JOB SHEET #4

M. Remove oil level gauge from swing gear compartment

N. Disconnect lines from manifold on swivel (Figure 27)

FIGURE 27



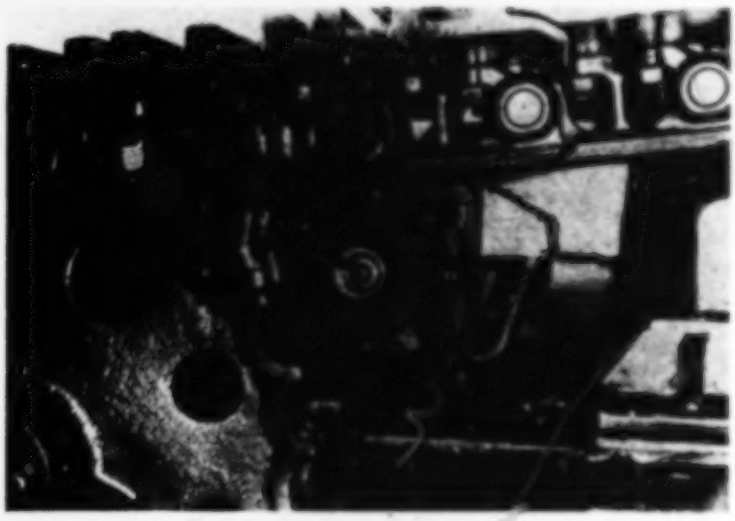
O. Disconnect any other lines that run from upper structure to undercarriage

P. Remove plug from each final drive

Q. Loosen nuts on input of final drives (Figure 28)

(NOTE: Loosening the nuts will disconnect final drive from the track motors so that undercarriage can be pulled from under the upper frame.)

FIGURE 28

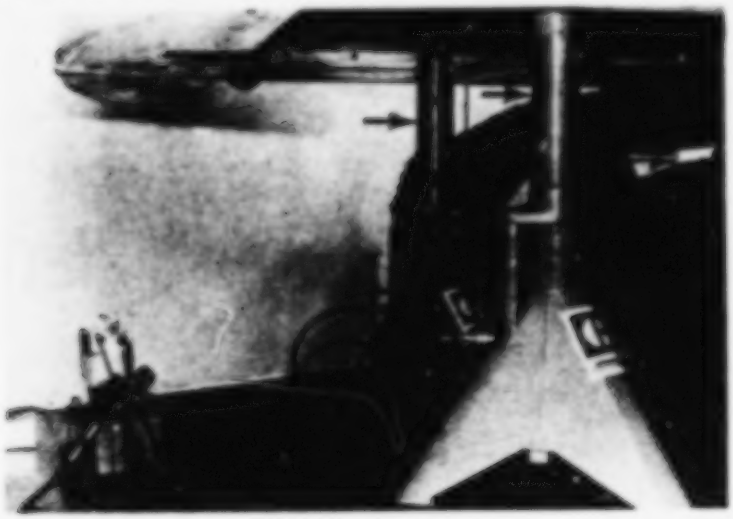


JOB SHEET #4

R. Position two jacks under rear of upper frame (Figure 29)

(NOTE: Jacks must operate independently in order to keep upper frame level.)

FIGURE 29



S. Position two jacks under boom (Figure 30)

FIGURE 30

T. Raise the two jacks under frame enough to keep upper frame level and straight

U. Remove remainder of bolts that hold upper frame to swing gear

V. Slowly raise two jacks under the upper frame until undercarriage will clear pinion on swing drive

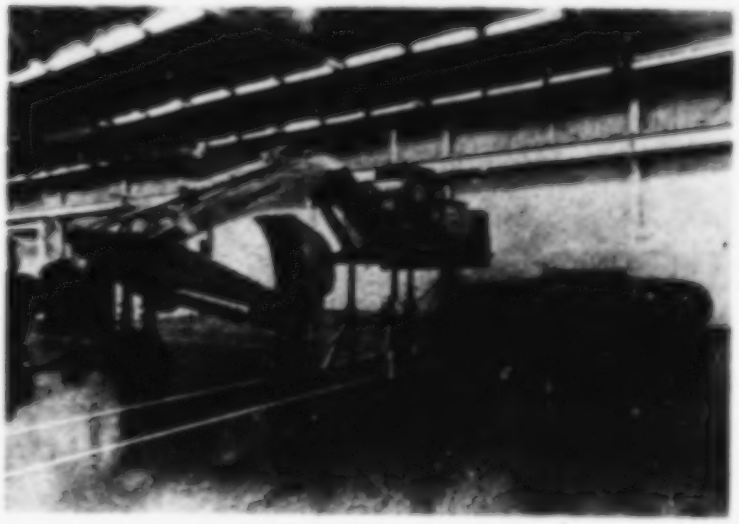
W. Fasten a chain or cable to undercarriage and to loader

X. Pull undercarriage from under upper frame (Figure 31)

FIGURE 31

Y. Install two jacks under front of upper frame for added support (Figure 32)

FIGURE 32

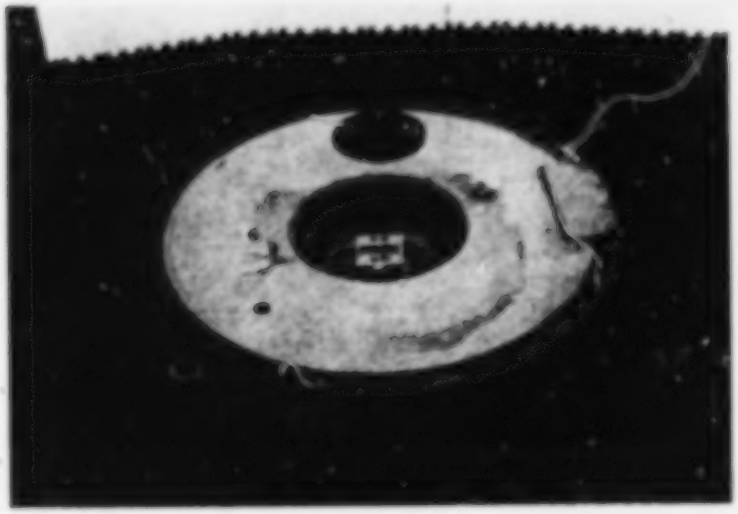


JOB SHEET #4

III. Procedure for replacing swing gear bearing unit and seals

A. Remove stripe and small cover from top of swing gear cover (Figure 33)

FIGURE 33



B. Use hoist to remove cover from swing gear and bearing

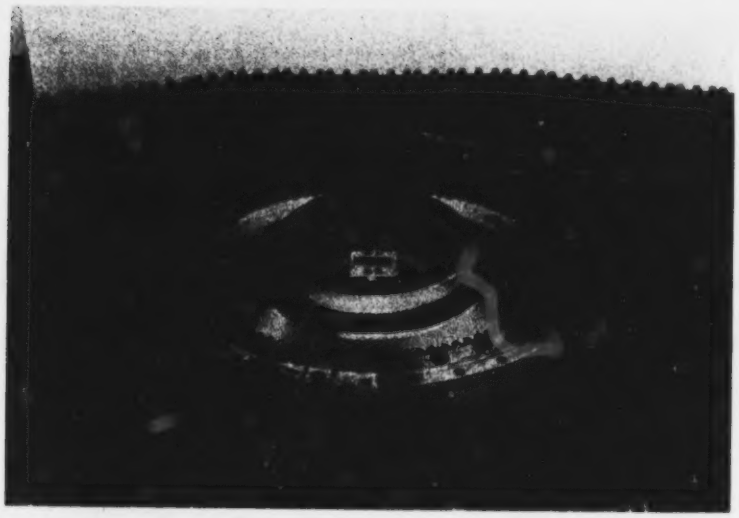
C. Remove all bolts holding swing gear unit to undercarriage (Figure 34)

FIGURE 34

JOB SHEET #4

D. Use the three 6-inch bolts to install the three lifting brackets to swing gear (Figure 35)

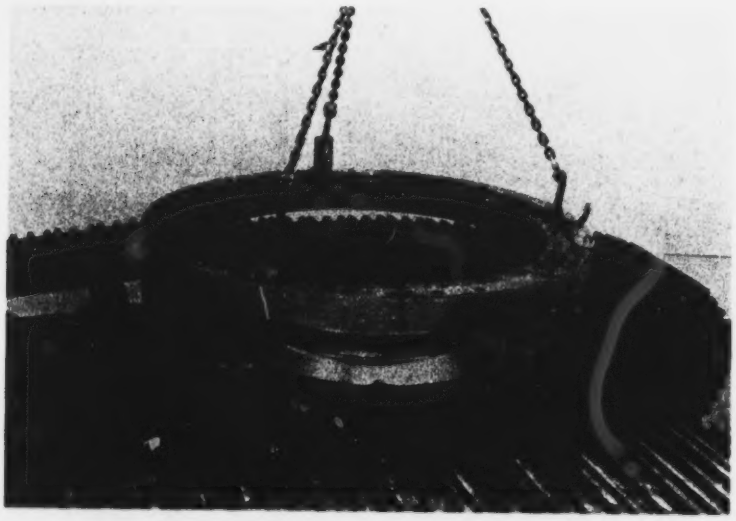
FIGURE 35



E. Connect hoist to brackets on swing gear unit

F. Raise hoist to remove swing gear unit (Figure 36)

FIGURE 36



JOB SHEET #4

G. Remove old seal from swing gear

H. Use help to remove pan from undercarriage (Figure 37)

FIGURE 37

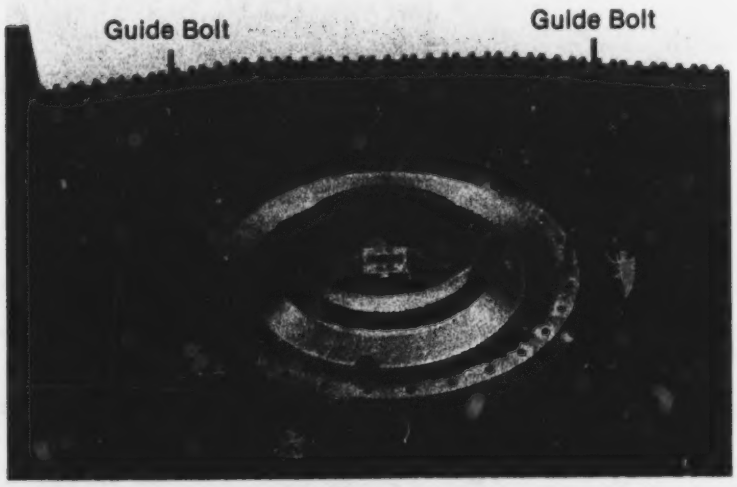
I. Remove old gasket material from contact surfaces of pan and undercarriage

J. Use liquid gasket material on the surfaces before installing new gasket

(NOTE: Clean and inspect complete system before reinstalling.)

K. Install the two 1" x 9 NC guide bolts and replace pan on undercarriage (Figure 38)

FIGURE 38



L. Apply contact cement to seal seat

M. Install new seal on pan

(NOTE: Do not let contact cement become dry before installing seal.)

N. Apply a light coat of grease to the seal surface that contacts the cover

O. Apply liquid gasket material to contact surfaces of pan and swing gear

P. Remove lifting brackets from old swing gear unit and install them on new swing gear

Q. Connect hoist to lifting brackets on new swing gear unit and replace on pan (Figure 39)

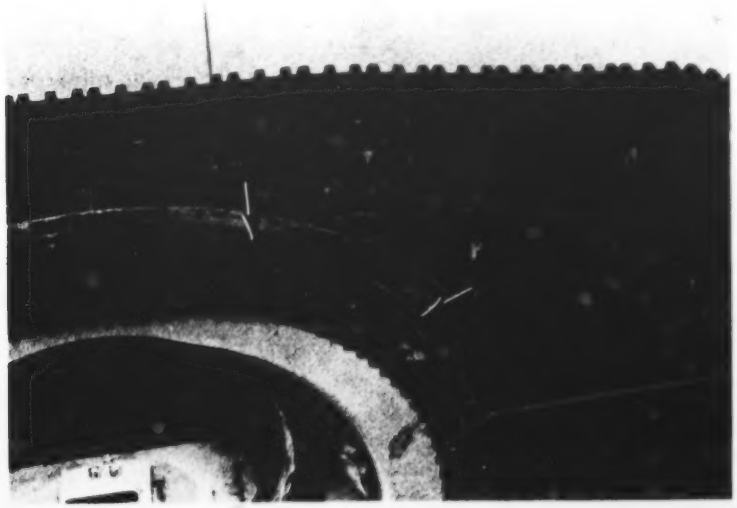
FIGURE 39

JOB SHEET #4

R. Reinstall hold-down bolts on swing gear unit (Figure 40)

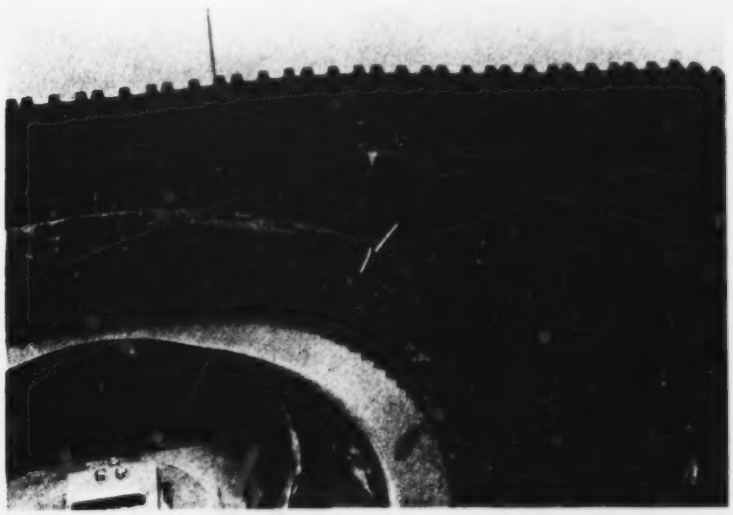
(NOTE: Torque all bolts according to specifications)

FIGURE 40



S. Install new seal around swing gear (Figure 41)

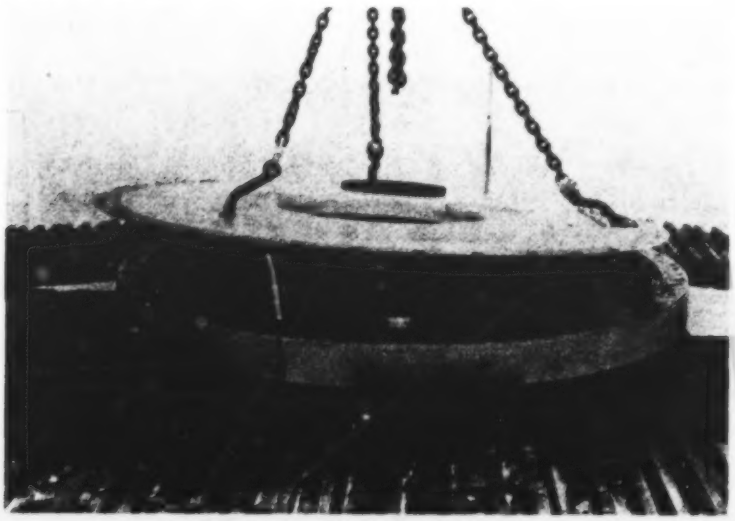
FIGURE 41



JOB SHEET #4

T. Connect hoist to cover and replace on swing gear (Figure 42)

FIGURE 42



U. Reinstall strips and small cover on top of swing gear

V. Remove two jacks from under front of upper structure

W. Move undercarriage under upper structure and align with upper structure

X. Lower two rear jacks slowly and carefully until upper structure rests on undercarriage

Y. Reinstall all bolts that hold upper frame to swing gear

Z. Reconnect all lines and fittings, reversing sequence used to disconnect them

AA. Reinstall and tighten nut on final input shaft

BB. Install plug in final drives

CC. Remove all braces, blocking plates, and jacks

DD. Refill swing gear oil compartment to correct level

(NOTE: Use oil recommended by manufacturer.)

EE. Check all controls for proper operation

FF. Clean work area; clean and put away all tools and equipment

DECK MACHINERY
UNIT III

TEST

NAME _____ SCORE _____

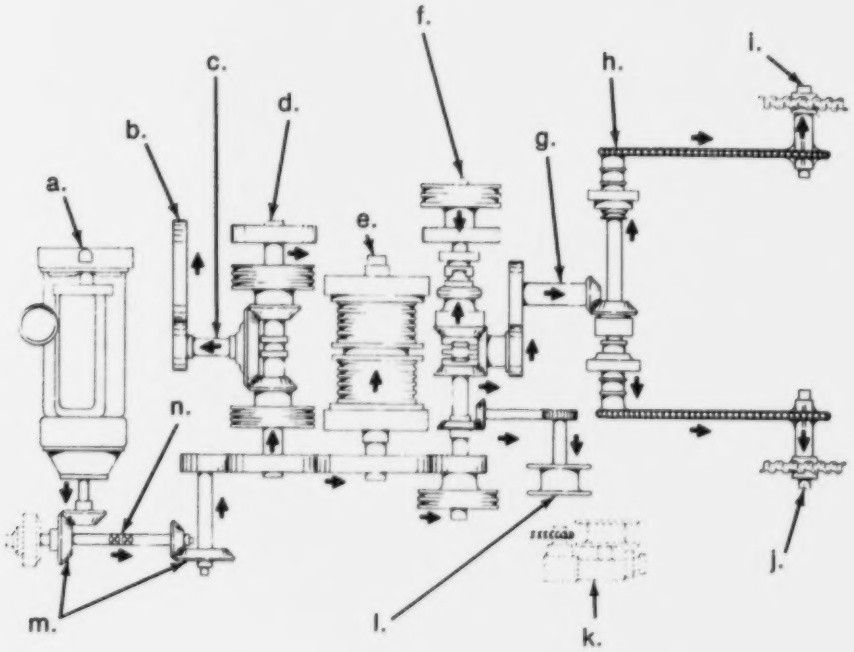
1. Match terms associated with deck machinery to their correct definitions. Write the correct numbers in the blanks.

_____a.	Pounds per square inch	1. Turntable
_____b.	Vertical pin connected at the bottom to another part; serves as a center of rotation	2. Shim
_____c.	Base that supports a part and allows it to rotate or swing	3. ±
_____d.	Hydraulic-type motor used to operate the swing or rotating unit of a machine	4. Pinion gear
_____e.	Thin piece of material used in a space for adjustment of fit	5. Eyebolt
_____f.	Smallest of a train of gears or the smaller of two meshing gears	6. psi
_____g.	Grooved wheel or pulley	7. Bull gear
_____h.	Bolt that has a looped or round head	8. Swing motor
_____i.	Toothed driving wheel that is the largest or strongest in the mechanism	9. Pintle
_____j.	Symbol for plus or minus tolerance	10. Sheave
_____k.	Equipment and machinery that are installed on the deck of a vehicle	11. Deck machinery

TEST

2. Identify basic parts of a deck layout. Write the correct names in the blanks. Answers may be used more than once.

Engine	**Vertical swing shaft**	**Horizontal propel shaft**
Swing gear	**Horizontal swing shaft**	**Vertical propel shaft**
Drum shaft	**Boom hoist shaft**	**Two-speed hoist**
Right-angle drive	**Travel shaft**	**Crawler drive**
Universal joint		



a. _____ h. _____

b. _____ i. _____

c. _____ j. _____

d. _____ k. _____

e. _____ l. _____

f. _____ m. _____

g. _____ n. _____

TEST

3. Name structural divisions of an excavator.

   a. _____

   b. _____

   c. _____

4. Describe the three sets of power trains on an excavator.

   a. Hoist — _____

   _____

   b. Swing — _____

   _____

   c. Propel — _____

   _____

5. Distinguish between an A-frame and a gantry. Write an "A" in the blank describing an A-frame and a "G" in the blank describing gantry.

   _____a. Steel structure on machinery deck projecting high above cab roof; supports boom cables on large equipment

   _____b. Steel structure on machinery deck with cross bar slightly above cab roof; carries sheaves for boom support line

6. List types of deck mountings and travel units.

   a. _____

   b. _____

   c. _____

7. List types of rotating supports (swing rollers.)

   a. _____

   b. _____

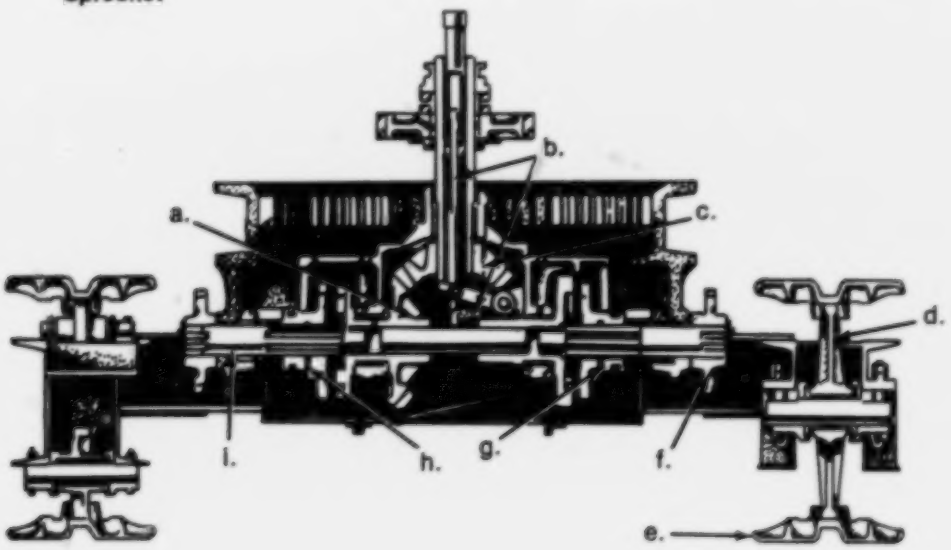
   c. _____

   d. _____

TEST

8. Identify basic parts of the propel power train below. Write the correct names in the blanks. Answers may be used more than once.

Bevel gear **Track** **Steering controls**
Bull wheel **Axle or drive shaft** **Clutch**
Sprocket



a. _____ f. _____

b. _____ g. _____

c. _____ h. _____

d. _____ i. _____

e. _____

(NOTE: Test question 9 lists the job sheets. They are an important part of this test. If they have not been completed, check with your instructor.)

9. Demonstrate the ability to

   a. Test control valves for speed and direction.

   b. Remove swing motor from hydraulic excavator.

   c. Disassemble swing brake, replace brake shoes, and reassemble swing brake.

   d. Remove excavator undercarriage; replace swing gear, bearing, seals, gasket; and reassemble excavator.

DECK MACHINERY
UNIT III

ANSWERS TO TEST

1.	a.	6	d.	8	g.	10	j.	3
	b.	9	e.	2	h.	5	k.	11
	c.	1	f.	4	i.	7		

2.	a.	Engine	h.	Travel shaft
	b.	Swing gear	i.	Crawler drive
	c.	Vertical swing shaft	j.	Crawler drive
	d.	Horizontal swing shaft	k.	Two-speed hoist
	e.	Drum shaft	l.	Boom hoist shaft
	f.	Horizontal propel shaft	m.	Right-angle drive
	g.	Vertical propel shaft	n.	Universal joint

3. a. Top or revolving unit (superstructure)
   b. Mounting or travel unit
   c. Various attachments

4. Description should include the following
   a. Hoist — Deck-mounted drums that control in/out and up/down movement of bucket
   b. Swing — Upper unit supported by rollers or bolts on a turntable, which rotates deck and swings boom in either direction
   c. Propel — Unit that provides means to walk or propel the vehicle

5. a. G
   b. A

ANSWERS TO TEST

6. a. Crawler
   b. Truck
   c. Rubber-wheeled, self-propelled

7. a. Swing rollers between two tracks
   b. Swing and hook rollers
   c. Bearing-type swing rollers
   d. Ball race

8. a. Bevel gear
   b. Steering controls
   c. Bevel gear
   d. Bull wheel
   e. Track
   f. Sprocket
   g. Clutch
   h. Clutch
   i. Axle or drive shaft

9. Performance skills evaluated to the satisfaction of the instructor

BOOMS AND OTHER ACCESSORIES
UNIT IV

UNIT OBJECTIVE

After completing this unit, the student should be able to adjust, remove, and reinstall various accessories used on equipment. The student will show this knowledge by completing job sheets and unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match to their correct definitions terms associated with booms and other accessories.
2. Label types of booms.
3. List types of accessories used on or with booms.
4. List miscellaneous accessories used on other equipment.
5. Demonstrate the ability to
   a. Install counterweight and pull hook on a crawler.
   b. Remove loader unit from crawler.
   c. Level a loader bucket.
   d. Remove bucket unit from a wheel loader.
   e. Remove backhoe assembly from a loader backhoe.
   f. Adjust circle on a motor grader.
   g. Adjust blade lift-control external brake on a motor grader.
   h. Install sections of boom on a crane.
   i. Install a boom jib on a crane.

BOOMS AND OTHER ACCESSORIES
UNIT IV

SUGGESTED ACTIVITIES

I. Suggested activities

A. Gather equipment and materials for job sheet demonstrations.

B. Provide students with objective sheet.

C. Discuss unit and specific objectives.

D. Provide students with information and job sheets.

E. Discuss information sheet.

F. Demonstrate and discuss procedures outlined in job sheets.

G. Give test.

H. When grading test questions 3 and 4, instructor should take into consideration that the students could list many correct answers other than those items listed in information sheet.

I. Complete appropriate section of competency profiles.

(NOTE: Competency profiles are available from AGC and CIMC.)

II. Instructional materials

A. Objective sheet

B. Suggested activities

C. Information sheet

D. Job sheets

1. Job Sheet #1 — Install Counterweight and Pull Hook on a Crawler
2. Job Sheet #2 — Remove Loader Unit from Crawler
3. Job Sheet #3 — Level a Loader Bucket
4. Job Sheet #4 — Remove Bucket Unit from a Wheel Loader
5. Job Sheet #5 — Remove Backhoe Assembly from a Loader Backhoe
6. Job Sheet #6 — Adjust Circle on a Motor Grader

SUGGESTED ACTIVITIES

7. Job Sheet #7 — Adjust Blade Lift-Control External Brake on a Motor Grader

8. Job Sheet #8 — Install Sections of Boom on a Crane

9. Job Sheet #9 — Install a Boom Jib on a Crane

E. Test

F. Answers to test

III. Unit references

A. *Buckeye Super B Series Selectioneered Ladder Ditchers.* Findlay, Ohio: Garwood Industries, Inc., n.d.

B. *850 Master Crawler Service Manual.* Racine, Wisconsin: JI Case, 1975.

C. *General Specifications Link-Belt 40-50 Ton (36-28-45, 35 Metric Ton) Wire Rope Crawler Excavator/Crane LS-128-DL/DLC.* Cedar Rapids, Iowa: FMC Corporation, n.d.

D. *General Specifications Link-Belt Hydraulic Crawler Excavator LS-6400.* Cedar Rapids, Iowa: FMC Corporation, n.d.

E. *John Deere JD 500-C Loader Backhoe Technical Manual TM-1038.* Moline, Illinois: Deere & Company, 1973.

F. *John Deere JD 544B Loader Technical Manual TM-1094.* Moline, Illinois: Deere & Company, 1973.

G. Nichols, Herbert L., Jr. *Moving the Earth,* 3rd ed. Greenwich, Connecticut: North Castle Books, 1976.

H. *Operating Instructions 60xc Hydrocrane.* South Milwaukee, Wisconsin: Bucyrus-Erie Company, n.d.

I. *Operation and Maintenance Instructions Caterpillar No. 12 Motor Grader.* Peoria, Illinois: Caterpillar Tractor Company, n.d.

J. *300 Hydro-Scopic Operator's Manual.* Winona, Minnesota: The Warner & Swasey Company, 1973.

BOOMS AND OTHER ACCESSORIES
UNIT IV

INFORMATION SHEET

I. Terms and definitions

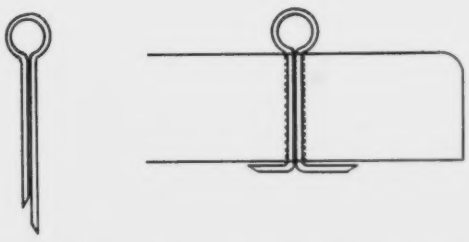
A. Boom — Any heavy beam that is hinged at one end and carries a weight-lifting device at the other; in a revolving shovel, a beam hinged to the deck front and supported by cables

B. Breaker ball — Round, steel ball used on crane hoist for demolition work

C. Cotter pin — Metal strip bent into a pin; ends can be flared after insertion through a hole or slot (Figure 1)

EXAMPLE:

FIGURE 1



D. Counterweight — Dead or nonworking load attached to machine to improve machine balance

E. Drawbar — Fixed or hinged bar extending to the rear; used to fasten lines for towing or moving loads

F. Drum — Rotating cylinder with side flanges; used for winding in and releasing cable

G. Drum-type tag line — Boom-mounted, spring-wound, automatic tag line used to keep clamshell bucket from twisting or spinning

H. Fairlead — Device that lines up cable so that it will wind smoothly onto a drum

I. Hook block — Assembly that includes safety hook, bearing block, thrust bearing, brass bushing, and side weights

J. Hydra boom — Hydraulically controlled boom mounted with air drills and feeds; can be mounted in any desired number on any type of base large and strong enough to carry them

INFORMATION SHEET

K. Jib — Extension hinged to upper end of boom

L. Mast — Tower or vertical beam carrying one or more load lines

M. Reeving — Threading or placement of working lines

N. Sheave — Grooved wheel used to support cable and change its direction of travel

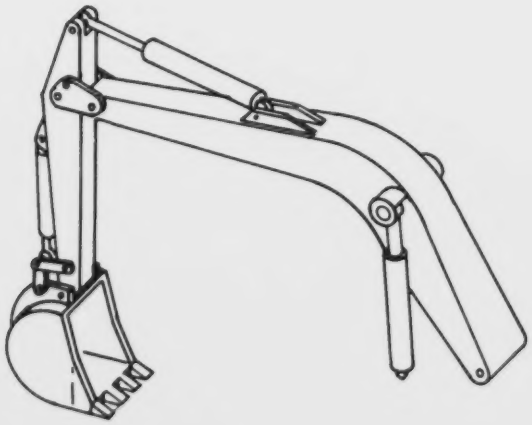
II. Types of booms (Figures 2-10)

A. Lattice-type crane boom

FIGURE 2

B. Hydraulic-type excavator

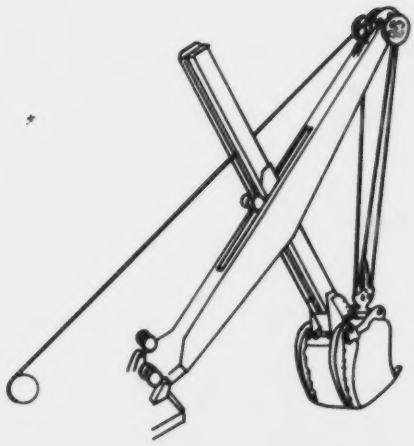
FIGURE 3



INFORMATION SHEET

C. Cable-type shovel

FIGURE 4



D. Hydraulic-type crane

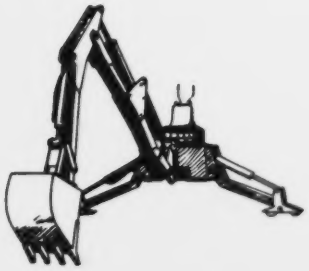
FIGURE 5

1657

INFORMATION SHEET

E. Hydraulic-type backhoe

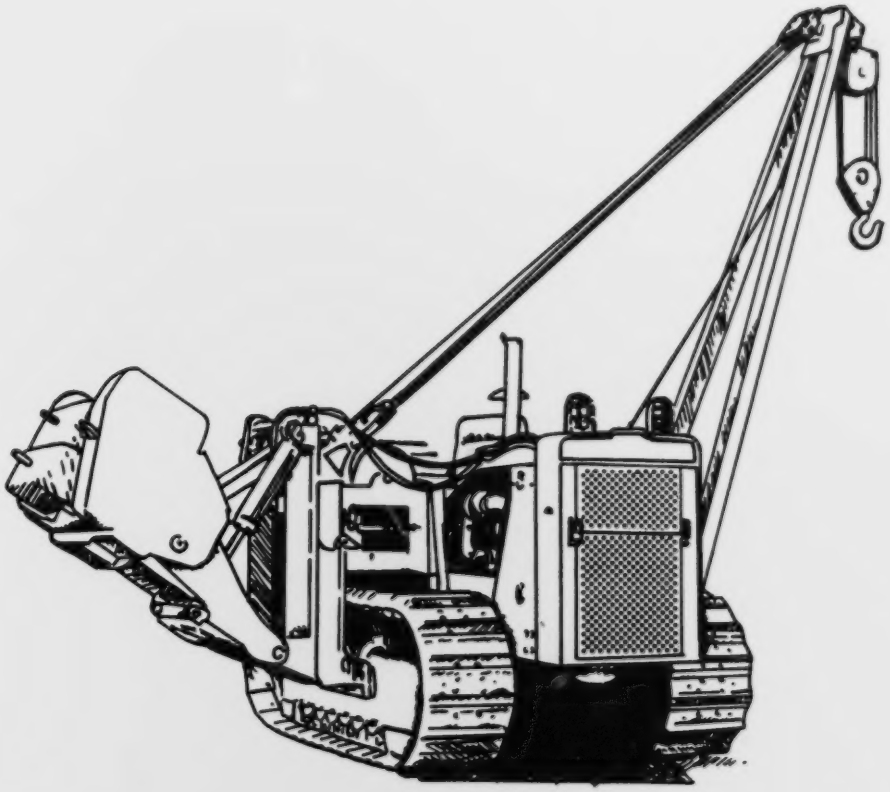
FIGURE 6



Used with permission of Ware Machine Works, Inc., Ware, Massachusetts.

F. Cable-type side boom

FIGURE 7

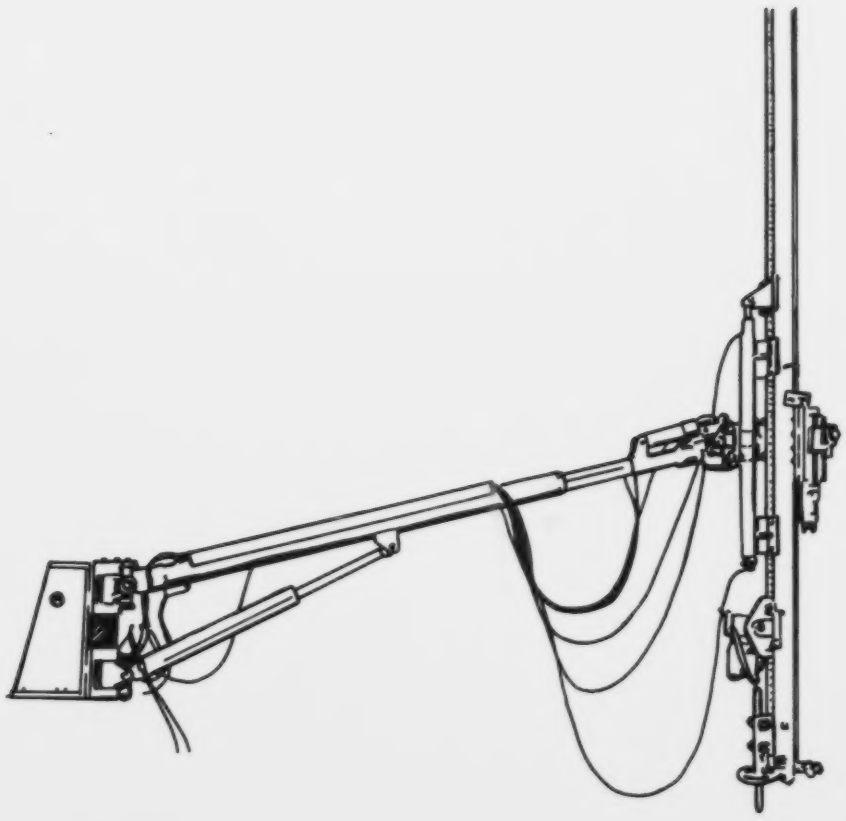


Used with permission of International Harvester.

INFORMATION SHEET

G. Hydra boom

FIGURE 8

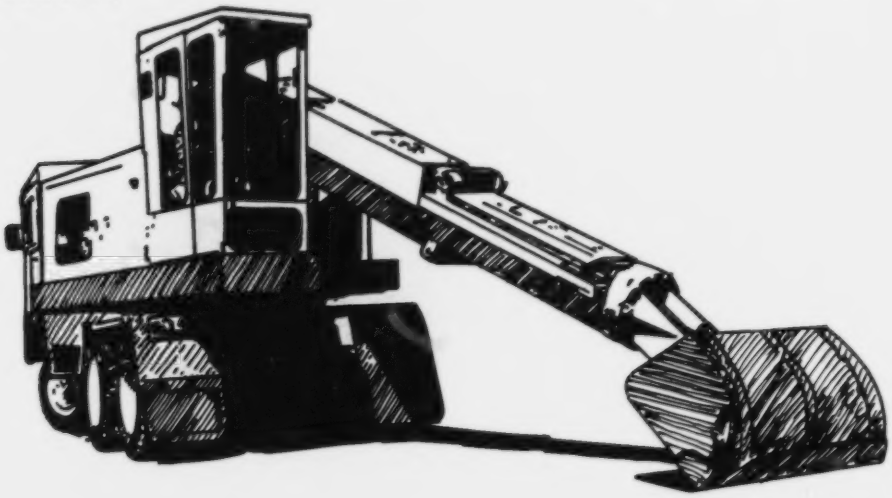


Used with permission of the Ingersoll-Rand Company.

INFORMATION SHEET

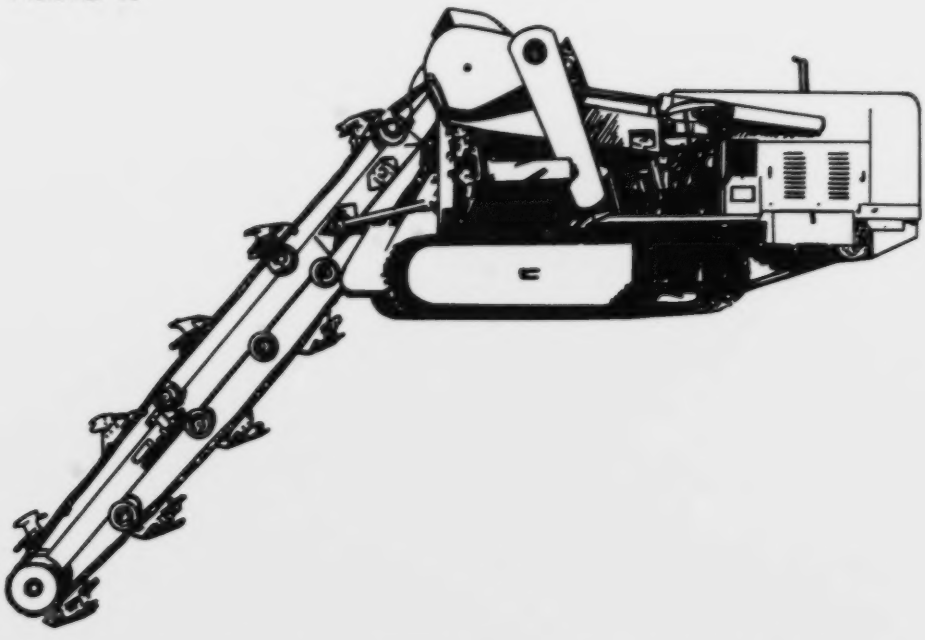
H. Hydraulic swivel-type boom

FIGURE 9



I. Hydraulic trencher-type boom

FIGURE 10



Source: *Buckeye Super B Series Selectioneered Ladder Ditchers,* Gar Wood Industries, Inc.

INFORMATION SHEET

III. Accessories used on or with booms

A. Dragline bucket

B. Clamshell bucket

C. Grapple

D. Breaker ball

E. Excavator bucket

F. Shovel bucket

G. Backhoe bucket

H. Fairlead

I. Drum-type tag line

J. Crane hook block

K. Overhaul ball and hook

L. Personnel and material buckets

M. Formed ditch-digging bucket

N. Ditcher

O. Magnet

P. Pavement-removal bucket

Q. Drilling equipment

R. Pile-driving equipment

S. Tamper (compactor)

T. Demolition hammer (jackhammer)

U. Boom extension

V. Jib

(NOTE: There are other accessories too numerous to list.)

INFORMATION SHEET

IV. Miscellaneous accessories used on other equipment

A. Dozer blade

B. Crawler loader bucket

C. Ripper

D. Root plow

E. Tree shear

F. Rake blade

G. V-blade

H. Angle blade

I. Winch

J. Cable layer

K. Auger drill

L. Paving breaker

M. Pile hammer

N. Tractor hammer

O. Grader blade (moldboard)

P. Grader scarifier

Q. Scraper bowl

R. Scraper apron

S. Wheel loader bucket

T. Slot loader bucket

U. Demolition bucket

V. Ejector bucket

W. Four-in-one bucket

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INFORMATION SHEET

X. Side dump loader

Y. Counterweights and pull hook

Z. Loader backhoe unit

AA. Crawler backhoe unit

BB. Trencher side boom and back filler

CC. Trencher conveyor

DD. Crawler drill

EE. Drawbar

(NOTE: There are other accessories too numerous to list.)

BOOMS AND OTHER ACCESSORIES
UNIT IV

JOB SHEET #1 — INSTALL COUNTERWEIGHT AND PULL HOOK ON A CRAWLER

I. Equipment and materials

A. Basic hand tool set

B. 1/2-inch or larger electric drill motor and a 1 1/16-inch drill

C. Heavy-duty jack

D. Torque wrench

E. 2 hex bolts, 1" x 4"; 2 washers, and 2 nuts

F. 4 hex bolts, 3/4" x 4 1/2"; 4 washers, and 4 nuts

G. 1,000-pound counterweight with pull hook

H. Shop towels

II. Procedure

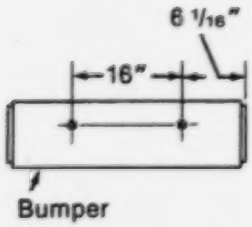
A. Support the front engine guard

B. Remove cap screws and washers that mount guard to engine frame

C. Remove front engine guard

D. Locate and drill two 1 1/16-inch holes in front bumper of engine frame (Figure 11)

FIGURE 11



Used with permission of J I Case, a Tenneco Company.

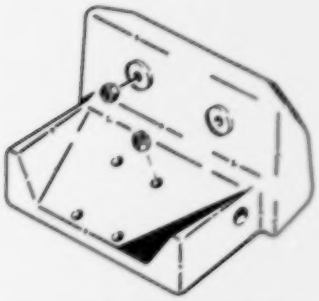
JOB SHEET #1

E. Raise counterweight into position for installation

(NOTE: Use the heavy-duty jack to raise counterweight.)

F. Install two front 1-inch hex bolts, washers, and nuts (Figure 12)

FIGURE 12

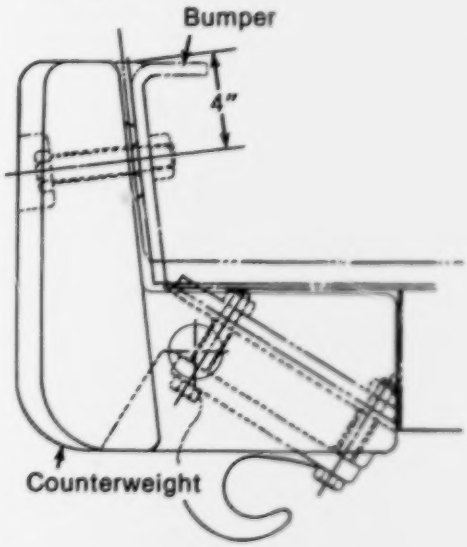


Used with permission of J I Case, a Tenneco Company.

G. Tighten and torque bolts to 660 to 680 foot-pounds

H. Position pull hook on underside of counterweight (Figure 13)

FIGURE 13



Used with permission of J I Case, a Tenneco Company.

JOB SHEET #1

I. Install the four 3/4-inch hex bolts, washers, and nuts

J. Tighten and torque bolts to 290 to 300 foot-pounds

K. Clean work area; clean and put away all equipment and materials

BOOMS AND OTHER ACCESSORIES
UNIT IV

JOB SHEET #2 — REMOVE LOADER UNIT FROM CRAWLER

I. Equipment and materials

A. Crawler with attached loader unit

B. Basic hand tool set

C. Hoist, at least 1 ½-ton capacity

D. Cap lugs

E. Shop towels

II. Procedure

A. Position crawler under hoist

B. Set bucket flat on ground

C. Move control lever back and forth and from side to side to relieve pressure in lift and tilt circuits

D. Move clam control lever back and forth to relieve pressure in circuit

E. Remove air cleaner cap, air cleaner pipe, and exhaust stack

F. Disconnect hoses

(NOTE: Refer to Figures 14 and 15 after Step I.)

1. Disconnect lift cylinder lines at tube-to-hose connection on each side of loader upright

2. Unclamp tubes from upright

(CAUTION: Close all openings with clean cap lugs as soon as possible to keep dirt out of system.)

3. Disconnect tilt cylinder hoses at the swivel fittings at closed end of right-hand slave cylinder and at antirollback valve of right-hand lift arm

4. Disconnect hoses at right-hand loader upright

G. Disconnect dump links from bucket; pivot dump links so that they rest on top edge of lift arms and do not dangle

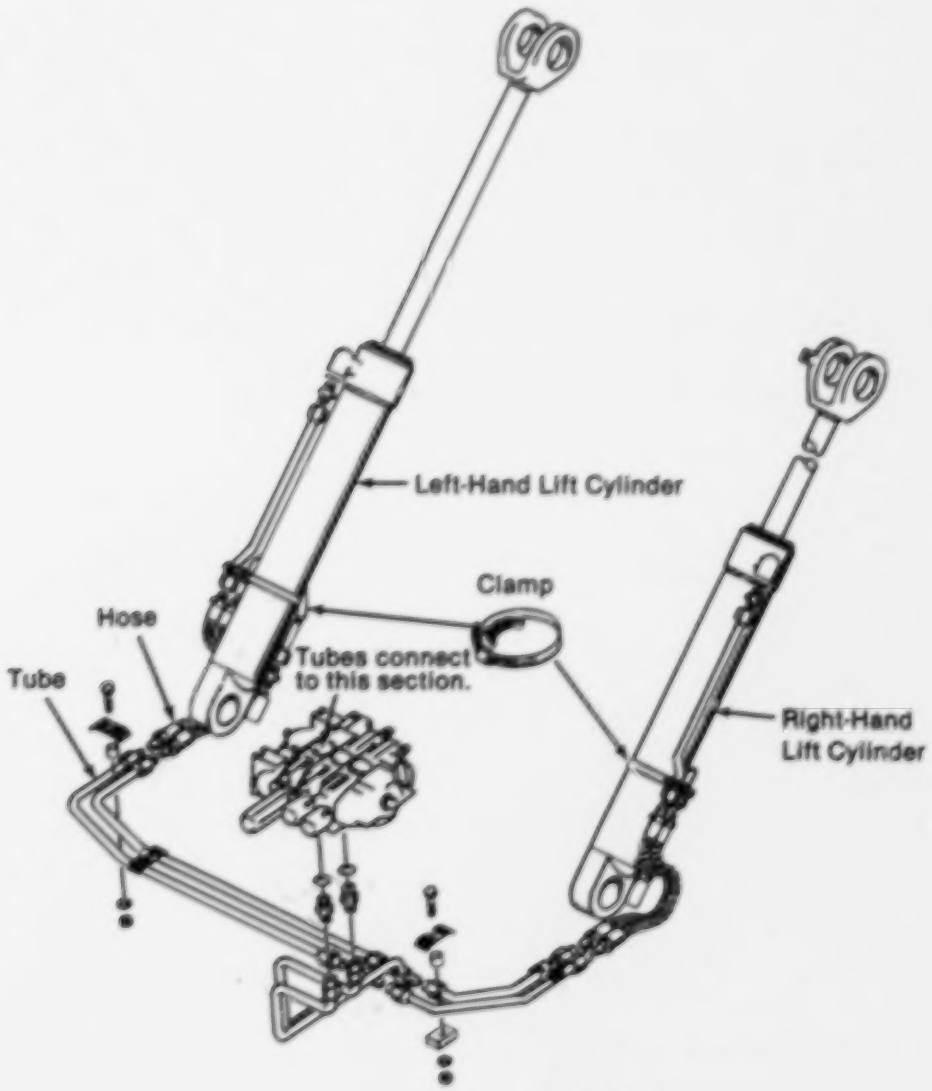
JOB SHEET #2

H. Disconnect wires used for return-to-dig mechanism

I. Attach hoist to loader

(NOTE: Be sure that hoist is securely and properly attached so that the load is balanced.)

FIGURE 14: Exploded View of Loader Lift Hydraulics



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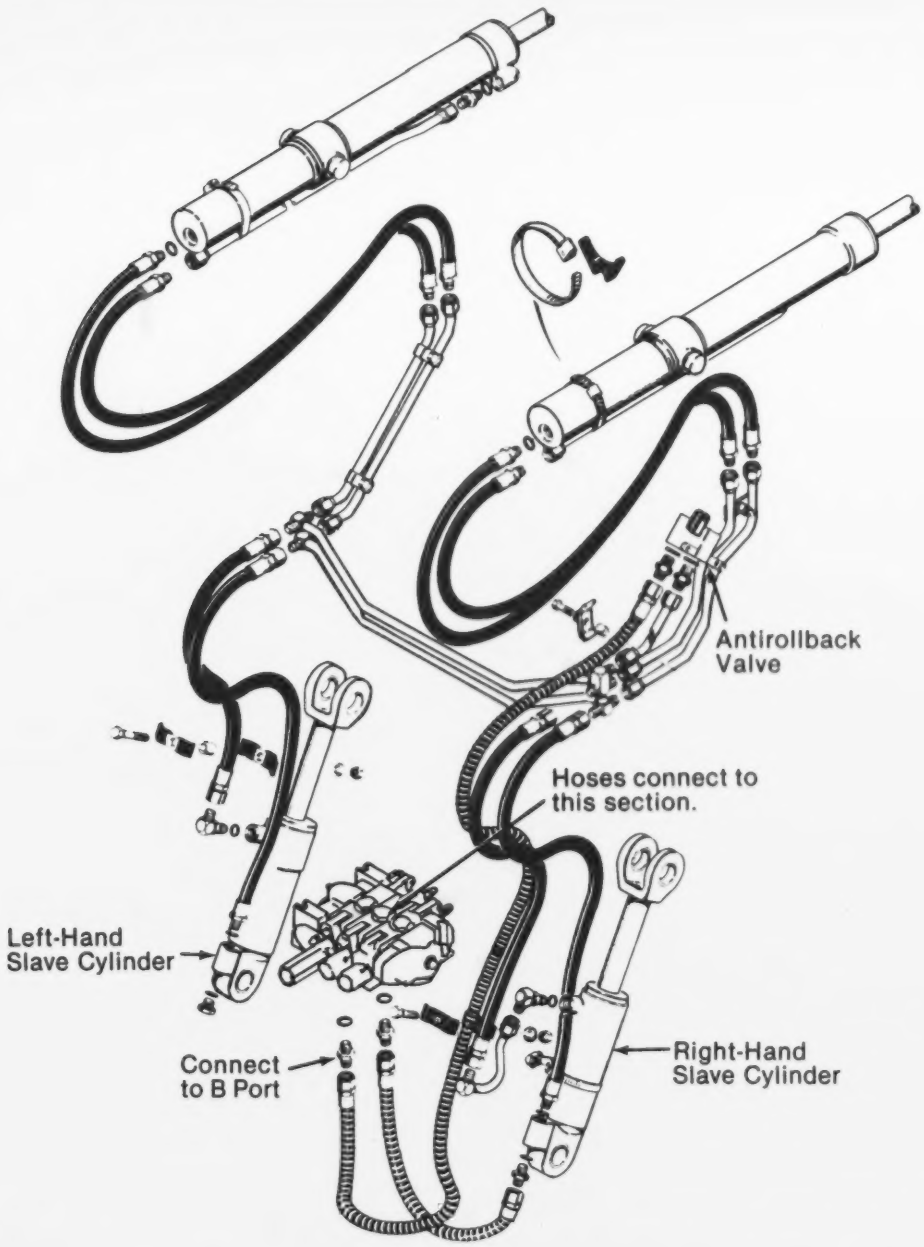
JOB SHEET #2

FIGURE 15: Exploded View of Loader Tilt Hydraulics



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JOB SHEET #2

J. Remove the four cap screws, washers, shims, and nuts from each side of loader where it is mounted to crawler frame

K. Raise loader carefully until loader frame foot pads are above the track

L. Start crawler and back from under loader

M. Lower loader to ground

(CAUTION: Do not operate the loader or clam control levers when the engine is running and the hoses are disconnected.)

N. Clean work area; clean and put away all equipment and materials

BOOMS AND OTHER ACCESSORIES
UNIT IV

JOB SHEET #3 — LEVEL A LOADER BUCKET

I. Equipment and materials

A. Crawler with loader bucket

B. Basic hand tool set

C. Assortment of shims

D. Shop towels

II. Procedure

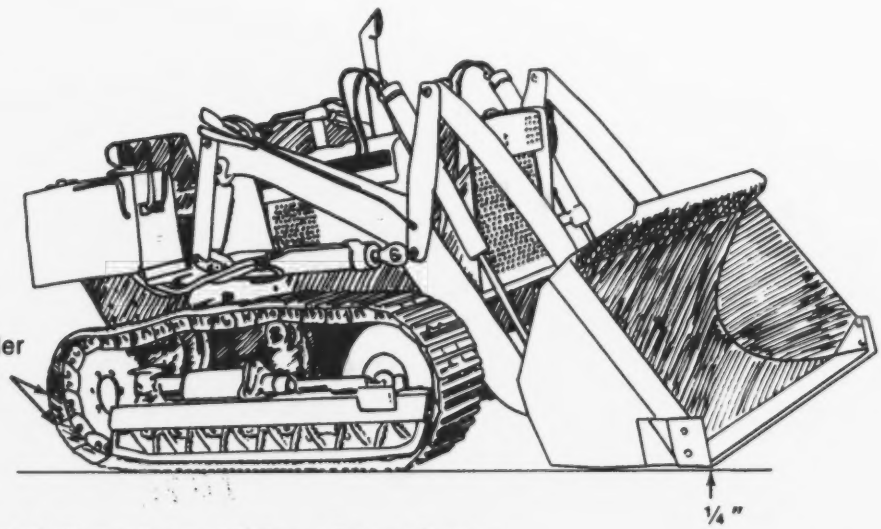
A. Position crawler on a level surface; lower bucket

B. Check level of bucket

(NOTE: Bucket should be level within 1/2 inch measured at the end of bucket.)

C. Lower bucket so that it is positioned within 1/4 inch of ground (Figure 16)

FIGURE 16



Adapted with permission of J I Case, a Tenneco Company.

JOB SHEET #3

D. Loosen the 1 1/4-inch bolts on mounting pads of loader uprights

E. Install shims under mounting pads on side that is low

(NOTE: Each shim will change the levelness approximately 1/4 inch.)

F. Tighten bolts on mounting pads

G. Recheck level of bucket

H. Clean work area; clean and put away all equipment and materials

BOOMS AND OTHER ACCESSORIES
UNIT IV

JOB SHEET #4 — REMOVE BUCKET UNIT FROM A WHEEL LOADER

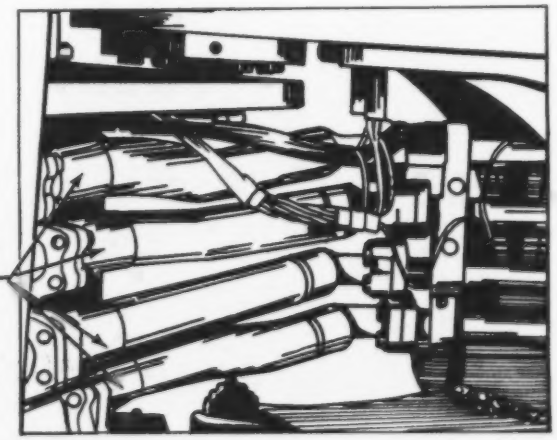
I. Equipment and materials

- A. Wheel loader with bucket
- B. Basic hand tool set
- C. Heavy-duty jack stands
- D. Heavy-duty jack
- E. Hoist
- F. Shop towels

II. Procedure

- A. Position loader on a level surface
- B. Disconnect battery ground strap
- C. Operate controls to release hydraulic pressure from system
- D. Disconnect loader hydraulic lines (Figure 17)

FIGURE 17

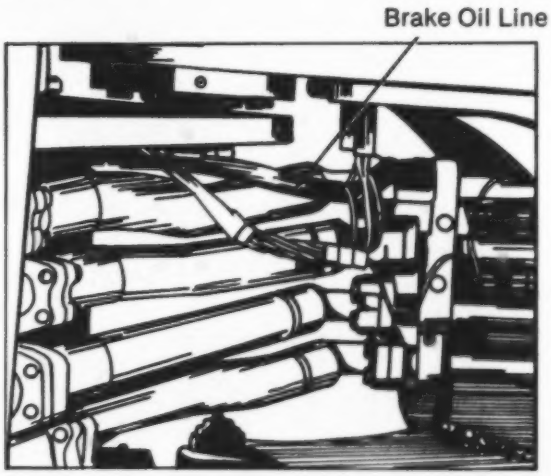


Adapted with permission of Deere and Company, Moline, Illinois.

JOB SHEET #4

E. Disconnect front brake oil line (Figure 18)

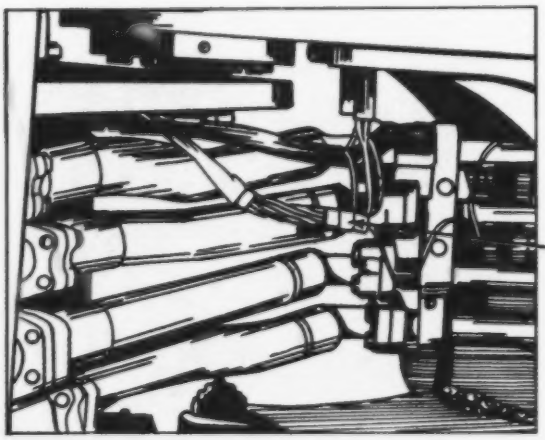
FIGURE 18



Adapted with permission of Deere and Company, Moline, Illinois.

F. Disconnect electrical connector block (Figure 19)

FIGURE 19



Adapted with permission of Deere and Company, Moline, Illinois.

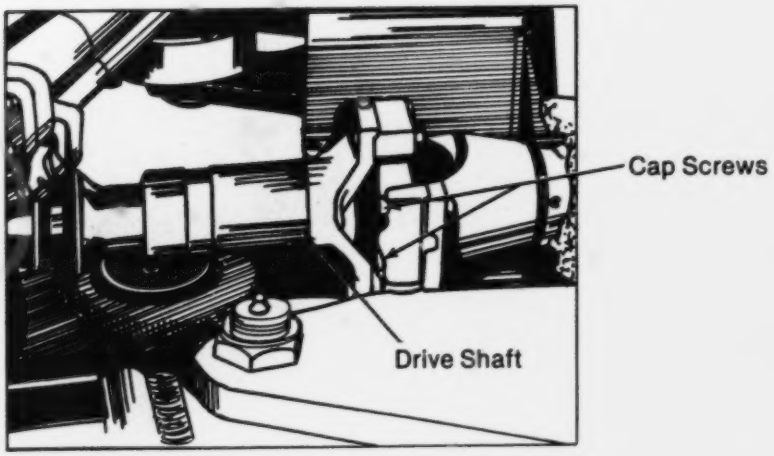
JOB SHEET #4

G. Remove cap screws from spider-to-shaft drive shaft

H. Disconnect telescoping drive shaft (Figure 20)

(NOTE: Push drive line toward engine frame.)

FIGURE 20



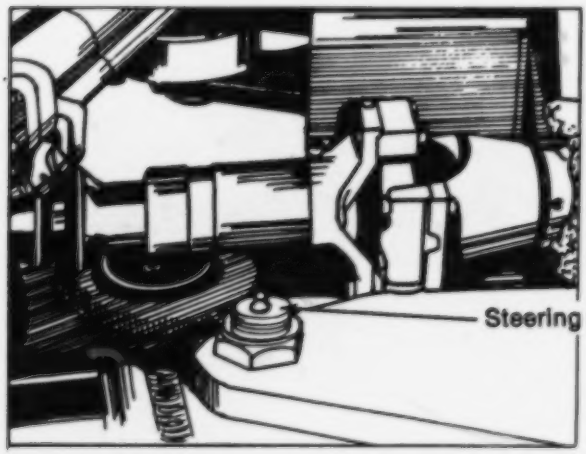
Adapted with permission of Deere and Company, Moline, Illinois.

JOB SHEET #4

I. Remove steering cylinder pivot pin (Figure 21)

(CAUTION: Do not damage threads on pivot pin while driving it out.)

FIGURE 21



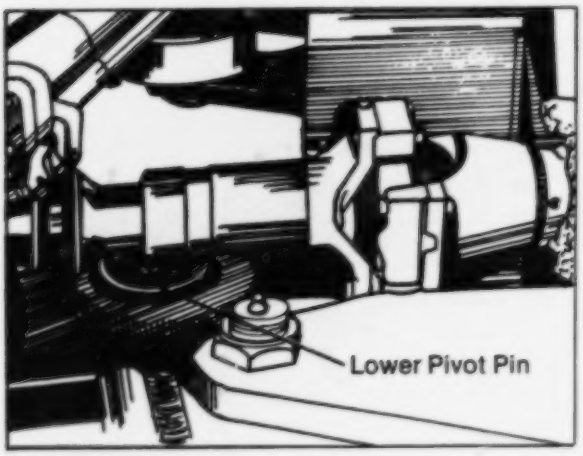
Adapted with permission of Deere and Company, Moline, Illinois.

J. Remove cap screw and grease fitting from lower pivot pin

JOB SHEET #4

K. Remove lower pivot pin (Figure 22)

FIGURE 22



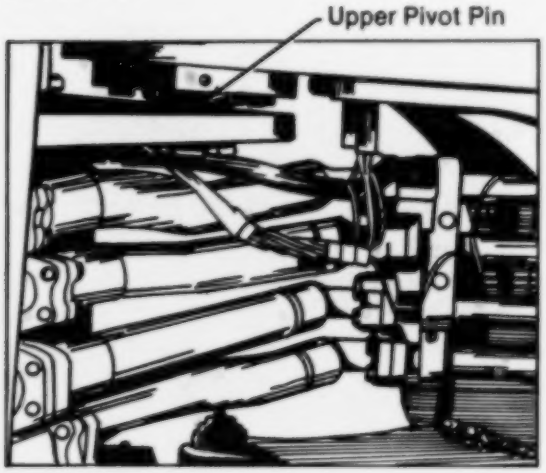
Adapted with permission of Deere and Company, Moline, Illinois.

L. Remove operator's platform

JOB SHEET #4

M. Remove upper pivot pin (Figure 23)

FIGURE 23



Adapted with permission of Deere and Company, Moline, Illinois.

N. Attach hoist to loader frame

O. Raise hoist, and roll loader away from engine frame

P. Clean work area; clean and put away all equipment and materials

BOOMS AND OTHER ACCESSORIES
UNIT IV

JOB SHEET #5 — REMOVE BACKHOE ASSEMBLY FROM A LOADER BACKHOE

I. Equipment and materials

A. Loader backhoe

B. Basic hand tool set

C. Jack stands

D. Assortment of cap plugs

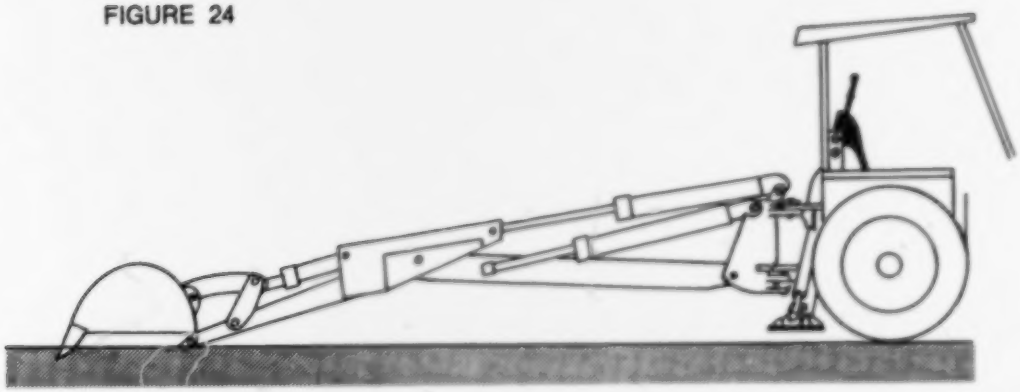
E. Shop towels

II. Procedure

A. Position backhoe on a level surface

B. Extend dipper stick, bucket, and boom to maximum position, with bucket resting on ground (Figure 24)

FIGURE 24



C. Lower stabilizers enough to raise rear wheels one at a time

(NOTE: This will align rear pin with cutout on wheel so that pin can be removed.)

D. Lower rear wheels, and apply just enough hydraulic pressure with the stabilizers to take weight off the mounting pin for easy removal

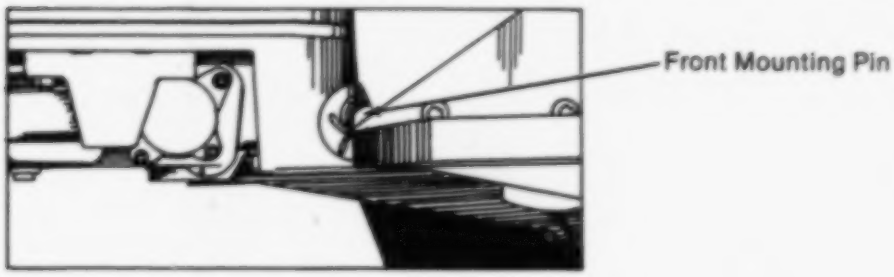
JOB SHEET #5

E. Place jack stands under main frame

F. Remove steps and mounting brackets

G. Remove from each side front mounting pins that connect tie bar to loader frame (Figure 25)

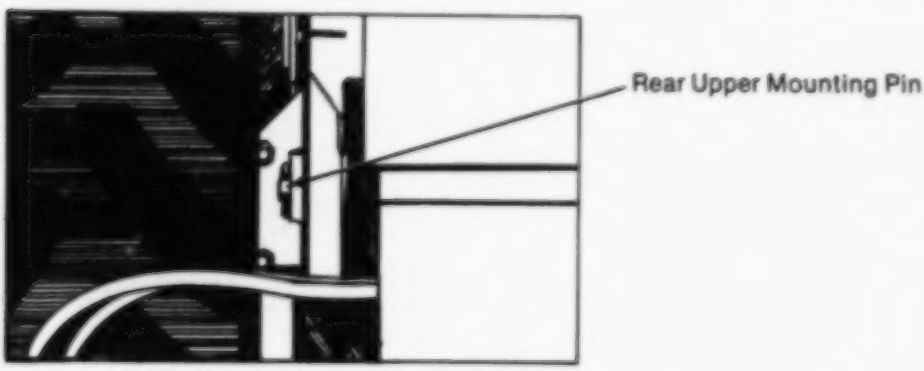
FIGURE 25



Adapted with permission of Deere and Company, Moline, Illinois.

H. Remove from each side rear upper mounting pins that connect backhoe frame to loader frame (Figure 26)

FIGURE 26



Adapted with permission of Deere and Company, Moline, Illinois.

I. Operate stabilizer controls to permit backhoe to rest solidly on jack stands

(CAUTION: Discharge hydraulic function accumulator. Operate loader control or stabilizer control until response ceases.)

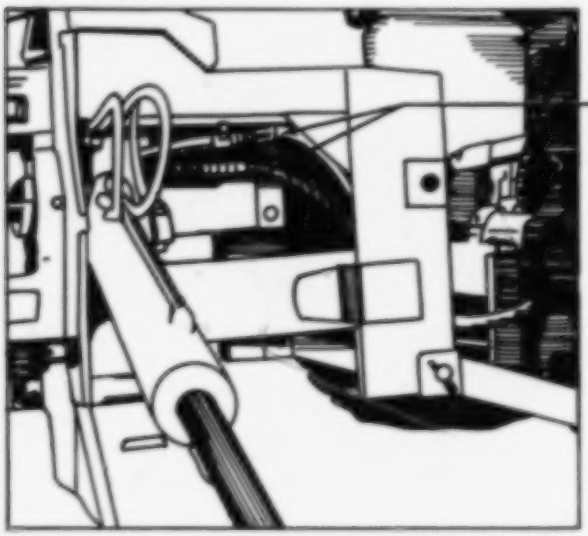
J. Disconnect backhoe pressure hose

JOB SHEET #5

K. Disconnect return hose

(NOTE: The return hose is located under the backhoe main frame. See Figure 27.)

FIGURE 27



Adapted with permission of Deere and Company, Moline, Illinois.

L. Place cap plugs over open lines

M. Remove jack stands, and move machine away from backhoe assembly

N. Clean work area; clean and put away all equipment and materials

BOOMS AND OTHER ACCESSORIES
UNIT IV

JOB SHEET #6 — ADJUST CIRCLE ON A MOTOR GRADER

I. Equipment and materials

A. Motor grader

B. Basic hand tool set

C. Assortment of shims

D. Shop towels

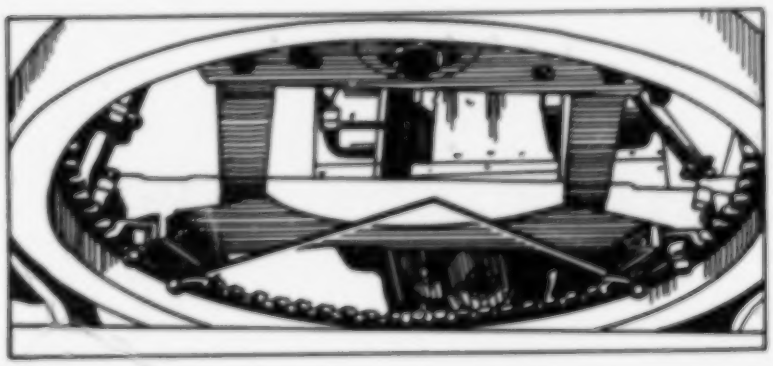
II. Procedure

(NOTE: Adjusting the circle on a motor grader eliminates side play and vertical play in the grader circle.)

A. Position grader on level ground

B. Loosen bolts holding guide shoes to frame (Figure 28)

FIGURE 28

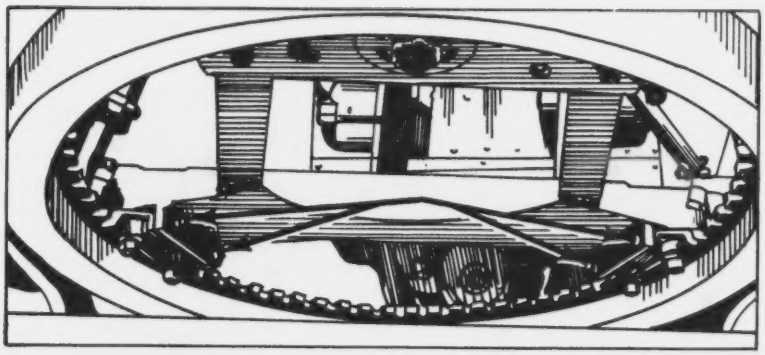


Adapted with permission of Caterpillar Tractor Co.

JOB SHEET #6

C. Loosen setscrew locknuts located on inner side of circle guides (Figure 29)

FIGURE 29



Adapted with permission of Caterpillar Tractor Co.

D. Turn setscrews down tight; then back off screws until circle turns freely

E. Tighten setscrew locknuts

(NOTE: Be sure that guides are adjusted equally, otherwise circle will bind at the front.)

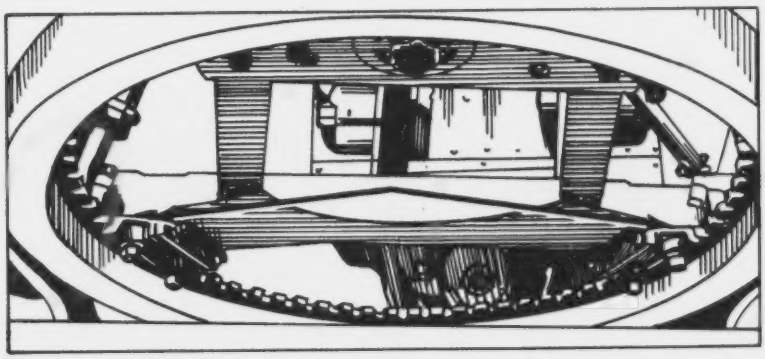
F. Retighten guide shoe bolts

JOB SHEET #6

G. Remove or add shims between circle drawbar and front and rear adjustable guide shoes (Figure 30)

(NOTE: These shims control the vertical play of the circle.)

FIGURE 30



Adapted with permission of Caterpillar Tractor Co.

H. Clean work area; clean and put away all equipment and materials

BOOMS AND OTHER ACCESSORIES
UNIT IV

JOB SHEET #7 — ADJUST BLADE LIFT-CONTROL EXTERNAL BRAKE ON A MOTOR GRADER

I. Equipment and materials

A. Basic hand tool set

B. Motor grader

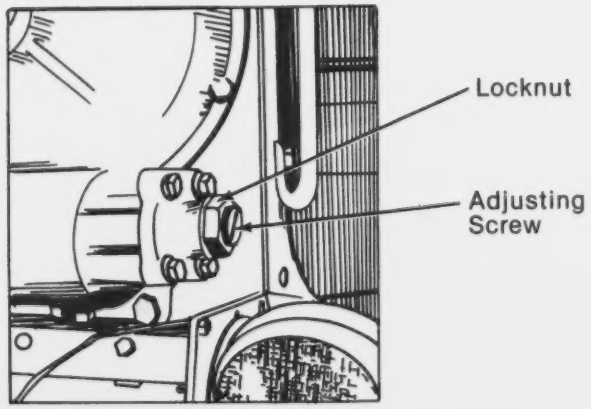
II. Procedure

(NOTE: Adjustment of brake preload spring tension prevents blade drop when operating the blade lift controls.)

A. Loosen locknut

B. Tighten adjusting screw until it bottoms (Figure 31)

FIGURE 31



Adapted with permission of Caterpillar Tractor Co.

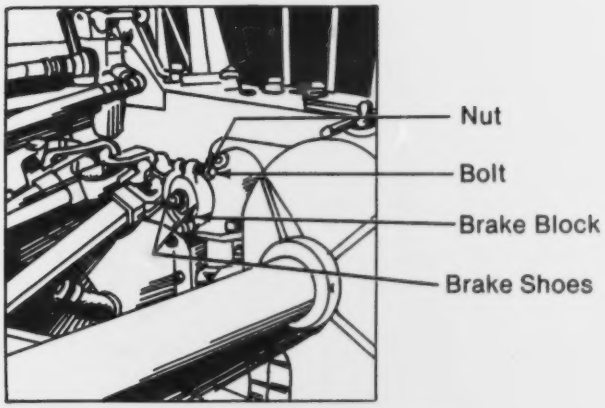
C. Tighten locknut

(NOTE: It may be necessary to hold adjusting screw while tightening locknut.)

JOB SHEET #7

D. Tighten nut on external brake until brake-shoe linings make contact with brake block (Figure 32)

FIGURE 32



Adapted with permission of Caterpillar Tractor Co.

E. Clean work area; clean and put away all equipment and materials

BOOMS AND OTHER ACCESSORIES
UNIT IV

JOB SHEET #8 — INSTALL SECTIONS OF BOOM ON A CRANE

I. Equipment and materials

- A. Crane
- B. Boom sections
- C. Blocking (for outriggers)
- D. Sledgehammer
- E. Tool kit
- F. Drift pins and cotter pins
- G. Gloves
- H. Appropriate-sized counterweight
- I. Shop towels
- J. Appropriate service manual

II. Procedure

(NOTE: Regardless of type or make of crane, it must be set up strictly in accordance with manufacturer's instructions and in a manner that will eliminate hazards to personnel, property, and the public.)

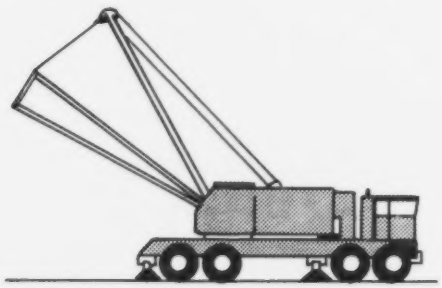
- A. Position crane on a level area
- B. Set swing lock

JOB SHEET #8

C. Set outriggers, and level machine (Figure 33)

(NOTE: Be sure that counterweight is sufficient for amount of boom being installed.)

FIGURE 33



D. Lay out boom sections near area where they will be installed (Figure 34)

(NOTE: Keep short sections nearest to boom foot [nearest to crane].)

FIGURE 34

JOB SHEET #8

E. Lower boom, and maneuver first section so that top pins can be installed (Figure 35)

FIGURE 35

F. Install pins and cotter pins

(NOTE: Sometimes it is necessary to drive these pins in.)

G. Maneuver remaining sections so that all top pins can be installed (Figure 36)

FIGURE 36

H. Install top pins and cotter pins in all top sections

I. Boom up slightly

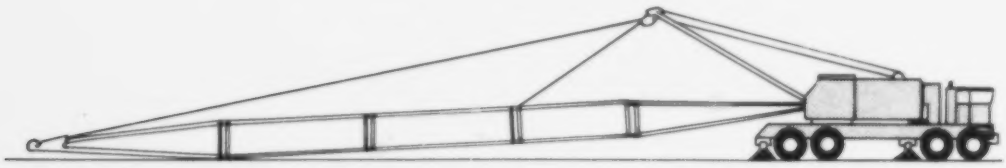
J. Use drift pin to align lower holes; then install lower pins and cotter pins

K. Boom down

JOB SHEET #8

L. Move pendant to last pinned section; attach midpoint suspension (Figure 37)

FIGURE 37



M. Clean work area; clean and put away all equipment and materials

BOOMS AND OTHER ACCESSORIES
UNIT IV

JOB SHEET #9 — INSTALL A BOOM JIB ON A CRANE

I. Equipment and materials

A. Basic hand tool set

B. Web sling

C. Auxiliary hoist or crane

D. Jib and installation pins and clips or locking pins

E. Mast unit

F. Shop towels

G. Blocking

II. Procedure

A. Position jib on ground

B. Install connecting pin and locking pin at each connecting joint

C. Inspect jib as it is being assembled to be sure there are no cracks or dents in any of the main chords, cross braces, or joints

(CAUTION: When handling jib with crane, be sure to use web slings. Do not choke the jib with a sling, causing chords to bend inward toward each other. Any damage to a main chord will require replacement.)

D. Place sling around lower section of jib

E. Attach sling to hoist line

F. Lift the base section of the jib onto blocking about 3 feet off the ground; remove hoist and sling

G. Attach hoist line to jib mast

H. Lift jib mast into its position on the mounting lugs of the jib base

I. Pin mast to the jib, and install locking pins

J. Continue to hold mast in vertical position with the hoist line

JOB SHEET #9

K. Install upper jib backstops, connecting the mast with the jib base section

(CAUTION: The telescoping jib backstops will come apart and allow the mast to fall if the mast is unsupported and is tipped backward [away from the jib point]. After the upper jib backstops have been installed, slack the hoist line and allow the mast to lean forward against the backstops. If the mast is allowed to tip backward without a support, it will fall and may cause injuries and/or damage to the machine.)

L. Pin the upper jib pendants to the equalizer link on the jib mast

M. Attach other end of the pendants to the jib point pin to obtain a 5-degree jib offset

(NOTE: If a 22-degree offset is necessary, insert the jib offset links between the end of the pendants and the jib point pin.)

N. Be sure the swing-around boom extension is in its working position

O. Boom down and line up point of the swing-around boom extension with the base of the jib

P. Pin jib base section to the swing-around boom extension

Q. Be sure to install all locking pins

R. Pin lower jib backstops to the mast and to the lugs on the swing-around boom extension point

S. Install lower jib pendants

T. Reeve hoist line over the mast idler sheave and over the jib point sheave

(NOTE: When reeving the jib, be sure to run the hoist line under the roller on the swing-around boom extension and over the jib mast deflector sheave.)

U. Clean work area; clean and put away all equipment and materials

Material in this job sheet adapted with permission of the Bucyrus-Erie Company.

BOOMS AND OTHER ACCESSORIES
UNIT IV

TEST

NAME _____ SCORE _____

1. Match to their correct definitions terms associated with booms and other accessories. Write the correct numbers in the blanks. Definitions continue on the following page.

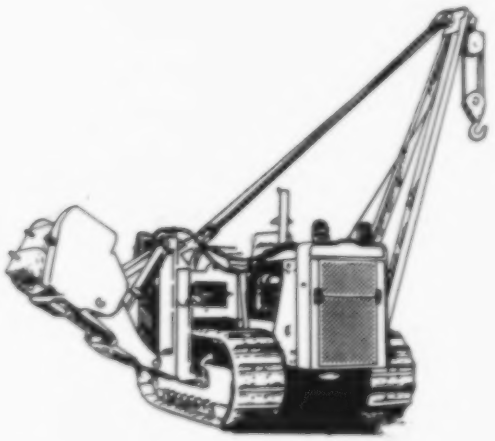
_____a.	Metal strip bent into a pin; ends can be flared after insertion through a hole or slot	1. Boom
_____b.	Device that lines up cable so that it will wind smoothly onto a drum	2. Mast
_____c.	Fixed or hinged bar extending to the rear; used to fasten lines for towing or moving loads	3. Sheave
_____d.	Extension hinged to upper end of boom	4. Cotter pin
_____e.	Any heavy beam that is hinged at one end and carries a weight-lifting device at the other; in a revolving shovel, a beam hinged to the deck front and supported by cables	5. Breaker ball
_____f.	Rotating cylinder with side flanges; used for winding in and releasing cable	6. Counterweight
_____g.	Round, steel ball used on crane hoist for demolition work	7. Drum-type tag line
_____h.	Threading or placement of working lines	8. Hydra boom
_____i.	Hydraulically controlled boom mounted with air drills and feeds; can be mounted in any desired number on any type of base large and strong enough to carry them	9. Drawbar
_____j.	Tower or vertical beam carrying one or more load lines	10. Hook block
_____k.	Boom-mounted, spring-wound, automatic tag line used to keep clamshell bucket from twisting or spinning	11. Reeving
_____l.	Grooved wheel used to support cable and change its direction of travel	12. Jib
		13. Fairlead
		14. Drum

TEST

_____m. Assembly that includes safety hook, bearing block, thrust bearing, brass bushing, and side weights

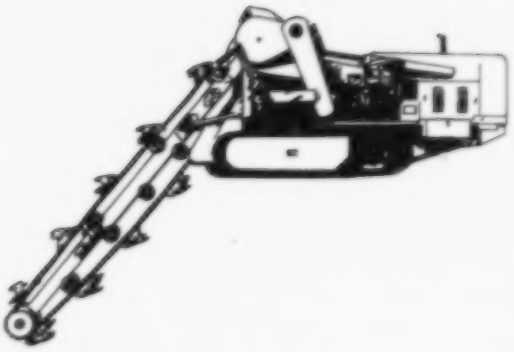
_____n. Dead or nonworking load attached to machine to improve machine balance

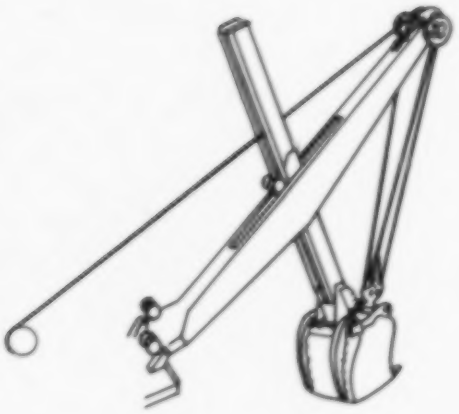
2. Label the following types of booms. Write the correct names in the blanks.



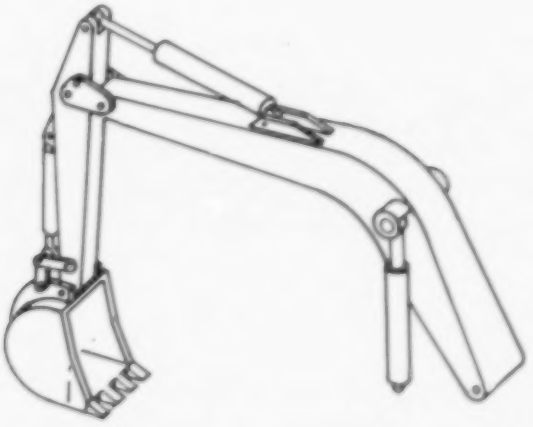
a. _____ b. _____

TEST





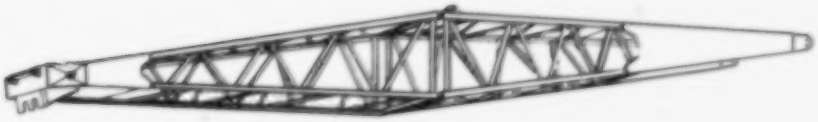
c. _____ d. _____



e. _____

TEST

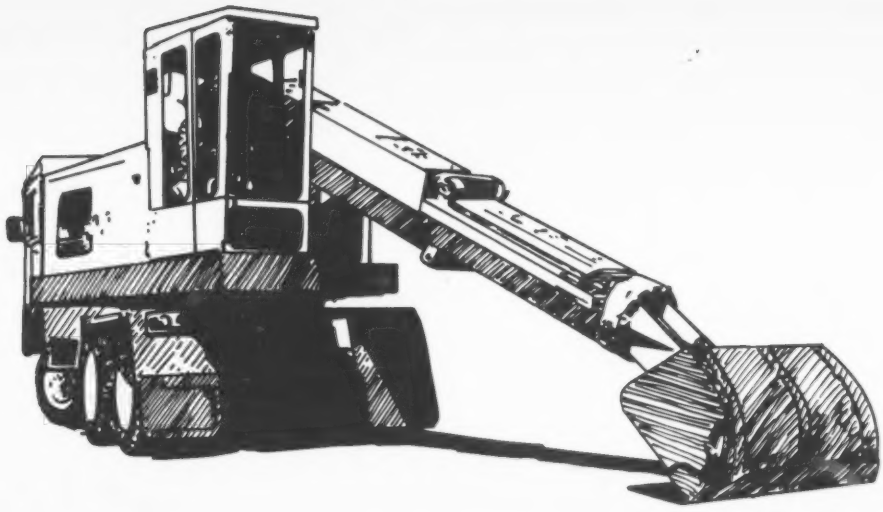
f. _____



g. _____

h. _____

TEST



i. _____

3. List twelve types of accessories used on or with booms.

a. _____

b. _____

c. _____

d. _____

e. _____

f. _____

g. _____

h. _____

i. _____

j. _____

k. _____

l. _____

TEST

4. List fifteen miscellaneous accessories used on other equipment.

a. _____

b. _____

c. _____

d. _____

e. _____

f. _____

g. _____

h. _____

i. _____

j. _____

k. _____

l. _____

m. _____

n. _____

o. _____

(NOTE: Test question 5 lists the job sheets. They are an important part of this test. If they have not been completed, check with your instructor.)

5. Demonstrate the ability to

a. Install counterweight and pull hook on a crawler.

b. Remove loader unit from crawler.

c. Level a loader bucket.

d. Remove bucket unit from a wheel loader.

e. Remove backhoe assembly from a loader backhoe.

f. Adjust circle on a motor grader.

TEST

g. Adjust blade lift-control external brake on a motor grader.

h. Install sections of boom on a crane.

i. Install a boom jib on a crane.

BOOMS AND OTHER ACCESSORIES
UNIT IV

ANSWERS TO TEST

1.

a.	4	h.	11
b.	13	i.	8
c.	9	j.	2
d.	12	k.	7
e.	1	l.	3
f.	14	m.	10
g.	5	n.	6

2.
a. Hydraulic-type crane
b. Cable-type side boom
c. Hydraulic trencher-type boom
d. Cable-type shovel
e. Hydraulic-type excavator
f. Hydra boom
g. Lattice-type crane boom
h. Hydraulic-type backhoe
i. Hydraulic swivel-type boom

3. Answer should include any twelve of the following
a. Dragline bucket
b. Clamshell bucket
c. Grapple
d. Breaker ball
e. Excavator bucket

ANSWERS TO TEST

f. Shovel bucket

g. Backhoe bucket

h. Fairlead

i. Drum-type tag line

j. Crane hook block

k. Overhaul ball and hook

l. Personnel and material buckets

m. Formed ditch-digging bucket

n. Ditcher

o. Magnet

p. Pavement-removal bucket

q. Drilling equipment

r. Pile-driving equipment

s. Tamper (compactor)

t. Demolition hammer (jackhammer)

u. Boom extension

v. Jib

4. Answer should include any fifteen of the following

a. Dozer blade

b. Crawler loader bucket

c. Ripper

d. Root plow

e. Tree shear

f. Rake blade

g. V-blade

h. Angle blade

ANSWERS TO TEST

i. Winch

j. Cable layer

k. Auger drill

l. Paving breaker

m. Pile hammer

n. Tractor hammer

o. Grader blade (moldboard)

p. Grader scarifier

q. Scraper bowl

r. Scraper apron

s. Wheel loader bucket

t. Slot loader bucket

u. Demolition bucket

v. Ejector bucket

w. Four-in-one bucket

x. Side dump loader

y. Counterweights and pull hook

z. Loader backhoe unit

aa. Crawler backhoe unit

bb. Trencher side boom and back filler

cc. Trencher conveyor

dd. Crawler drill

ee. Drawbar

5. Performance skills evaluated to the satisfaction of the instructor

STEERING SYSTEMS
UNIT I

UNIT OBJECTIVE

After completing this unit, the student should be able to identify different types of steering systems, inspect steering systems, and pressure-test power systems. The student will show this knowledge by completing job sheets and unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match to their correct definitions terms associated with steering systems.
2. Name major types of steering systems.
3. Label basic parts of the steering system.
4. Name types of manual steering gears.
5. List factors involved in steering a conventional or crawler tractor.
6. List wheel alignment angles.
7. Match wheel alignment angles to their correct functions.
8. Select from a list results of improper wheel alignment.
9. List steering parts that should be inspected for wear, adjustment, and damage.
10. Demonstrate the ability to
    a. Inspect a steering system for damaged parts and wear.
    b. Remove and replace a tie rod end.
    c. Pressure test a power steering system.
    d. Remove, reseal, and replace a power steering pump.

STEERING SYSTEMS
UNIT I

SUGGESTED ACTIVITIES

I. Suggested activities

A. Order films to supplement unit.

(NOTE: Large equipment manufacturers are excellent sources for slide and film presentations. Write directly to the appropriate company or manufacturer.)

B. Obtain transparencies.

(NOTE: Transparencies are available from AGC and CIMC.)

C. Gather equipment and materials for job sheet demonstrations.

D. Provide students with objective sheet.

E. Discuss unit and specific objectives.

F. Provide students with information and job sheets.

G. Discuss information sheet.

H. Demonstrate and discuss procedures outlined in job sheets.

I. Give test.

J. Complete appropriate section of competency profiles.

(NOTE: Competency profiles are available from AGC and CIMC.)

II. Instructional materials

A. Objective sheet

B. Suggested activities

C. Information sheet

D. Transparency masters

1. TM #1 — Mechanical Steering System
2. TM #2 — Hydrostatic Steering System
3. TM #3 — Hydraulic Steering System with Mechanical Drag Link

SUGGESTED ACTIVITIES

4. TM #4 — Hydraulic Assist System

5. TM #5 — Types of Manual Steering Gears

E. Job Sheets

1. Job Sheet #1 — Inspect a Steering System for Damaged Parts and Wear

2. Job Sheet #2 — Remove and Replace a Tie Rod End

3. Job Sheet #3 — Pressure Test a Power Steering System

4. Job Sheet #4 — Remove, Reseal, and Replace a Power Steering Pump

F. Test

G. Answers to test

III. Unit references

A. Armstrong, Ivan J. *Auto Mechanics,* Vol. I. Stillwater, Oklahoma: State Department of Vocational and Technical Education/Curriculum and Instructional Materials Center, 1976.

B. *FOS, Fundamentals of Service: Hydraulics,* 2nd ed. Moline, Illinois: Deere & Company, 1972.

C. Departments of the Army and the Air Force. *Principles of Automotive Vehicles,* (TM 9-8000-TO-36A-1-76). Washington D.C.: U.S. Government Printing Office, 1956.

STEERING SYSTEMS
UNIT I

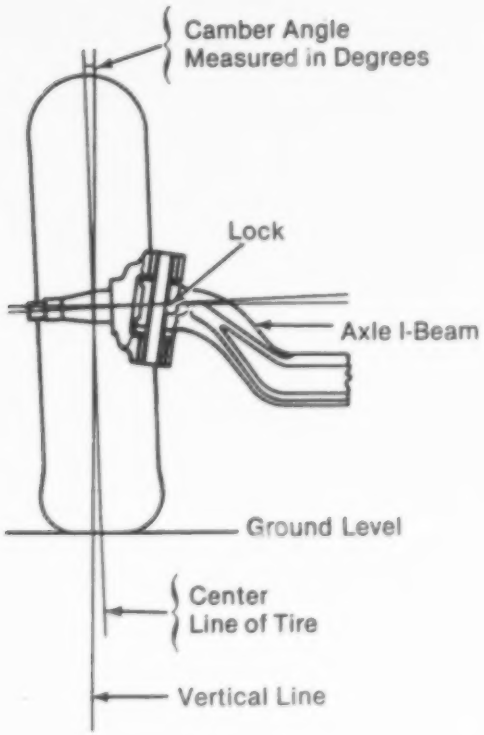
INFORMATION SHEET

I. Terms and definitions

A. Camber — Angle of wheel with the vertical when it is in straight-ahead position (Figure 1)

EXAMPLE:

FIGURE 1

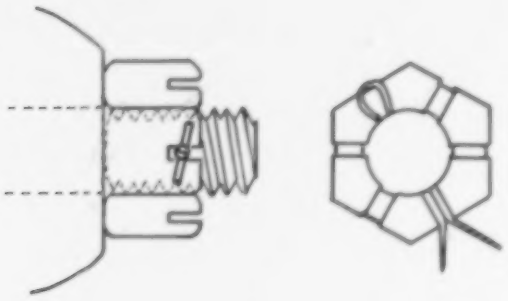


INFORMATION SHEET

B. Castellated nut — Hex-shaped nut with slots that line up with hole in shaft or spindle so that cotter pin can be inserted to lock nut in place (Figure 2)

EXAMPLE:

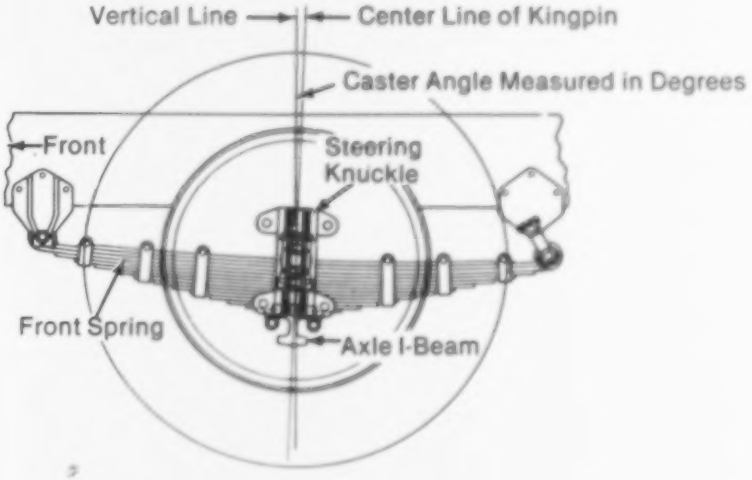
FIGURE 2



C. Caster — Number of degrees that steering knuckle pivots are tilted forward or backward from the vertical when viewed from the side (Figure 3)

EXAMPLE:

FIGURE 3

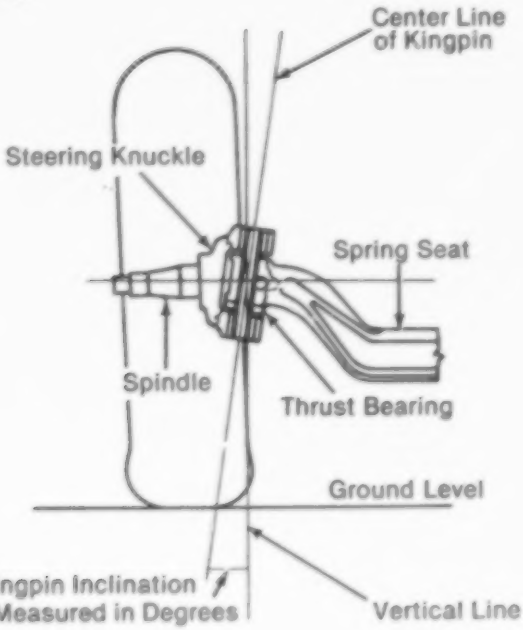


INFORMATION SHEET

D. Kingpin inclination — Number of degrees that steering knuckle pivots are tilted sideways toward center of vehicle (Figure 4)

EXAMPLE:

FIGURE 4



E. Over-center high point — Gear tooth mesh at its closest tolerance at center of worm and sector gear travel

F. Steering gear — Part of steering system located at lower end of steering column; transfers rotary motion of steering wheel to vehicle wheels

G. Steering linkage — Linkage between steering gear and vehicle wheels

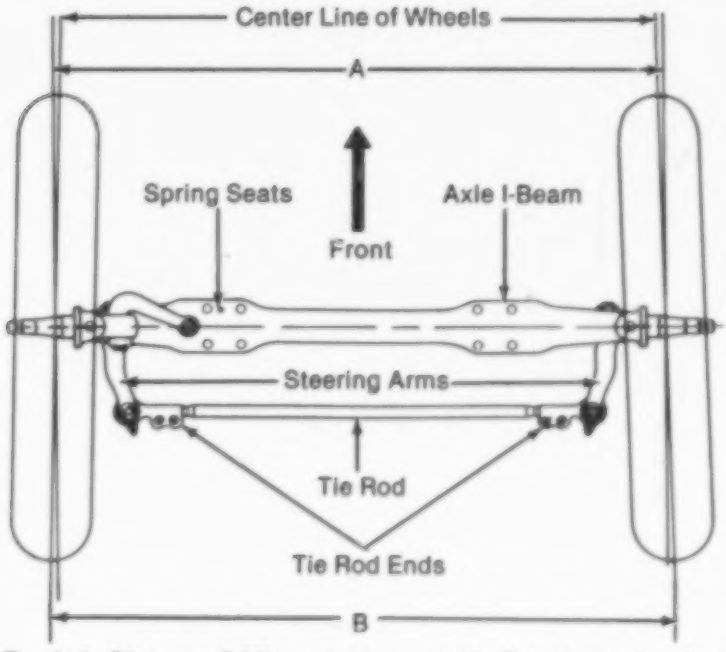
H. Steering system — System of gears and linkage in vehicle that permits driver to turn wheels for changing direction of travel

INFORMATION SHEET

I. Toe-in — Amount in inches that wheels point in; distance between front of wheels is less than distance between rear of wheels (Figure 5)

EXAMPLE:

FIGURE 5



Toe-In Is Distance B Minus A, Measured in Fractions of an Inch

J. Toe-out — Difference in turning ratios of wheels when turning

K. Wheel alignment — Mechanics of keeping all parts of steering system properly adjusted

II. Major types of steering systems (Transparencies #1-#4)

A. Mechanical (manual)

B. Power

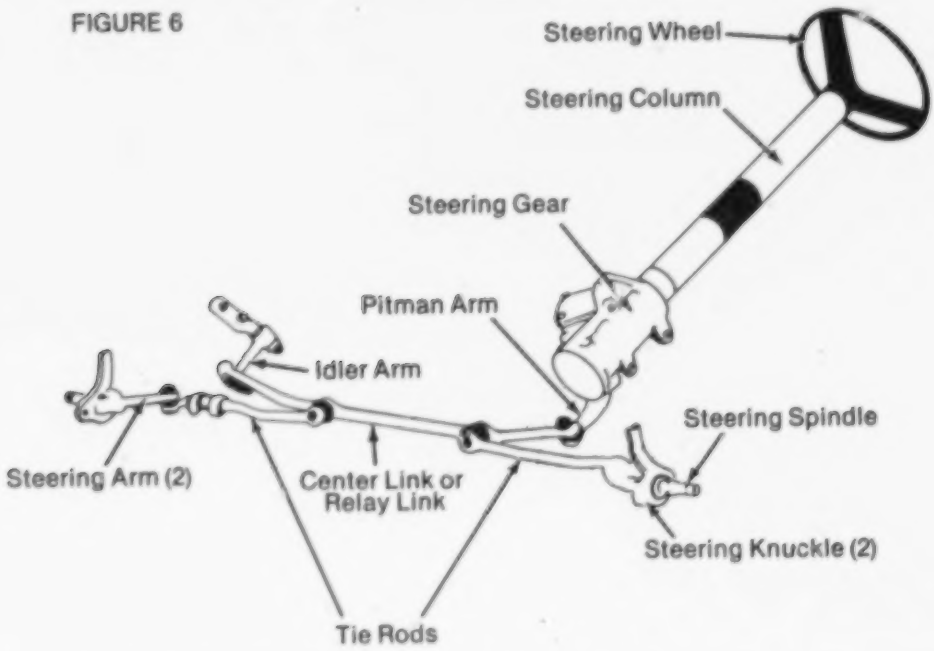
(NOTE: Power steering systems are divided into two major categories: hydraulic steering with mechanical drag link, and hydrostatic steering.)

C. Hydraulic assist

INFORMATION SHEET

III. Basic parts of steering system (Figure 6)

FIGURE 6



IV. Types of manual steering gears (Transparency #5)

A. Recirculating ball nut and worm

B. Worm and sector

C. Rack and pinion

V. Factors involved in steering a conventional or crawler tractor

A. Steering clutches

B. Steering brakes

C. Footing

D. Load being pulled or pushed

VI. Wheel alignment angles

A. Toe-out

B. Caster

INFORMATION SHEET

C. Camber

D. Kingpin (steering axis) inclination

E. Toe-in

VII. Functions of wheel alignment angles

A. Toe-out — Allows inner front wheel to roll freely on turns, and prevents outer wheel from dragging

B. Caster — Enables front wheels to maintain a straight-ahead position or return to a straight-ahead position after a turn has been completed

C. Camber — Brings road contact point of tire more nearly under point of load, and eliminates excessive tire wear

D. Kingpin inclination — Aids steering stability and establishes a pivot point about which the wheel can be easily turned

E. Toe-in — Compensates for varying tolerances in steering linkage, and prevents excessive tire wear

VIII. Results of improper wheel alignment

A. Vehicle pulls to left or right

B. Vehicle shimmies

C. Vehicle wanders

D. Tires wear improperly

E. Steering may be hard or erratic

IX. Steering parts to inspect for wear, adjustment, and damage

A. Steering gear

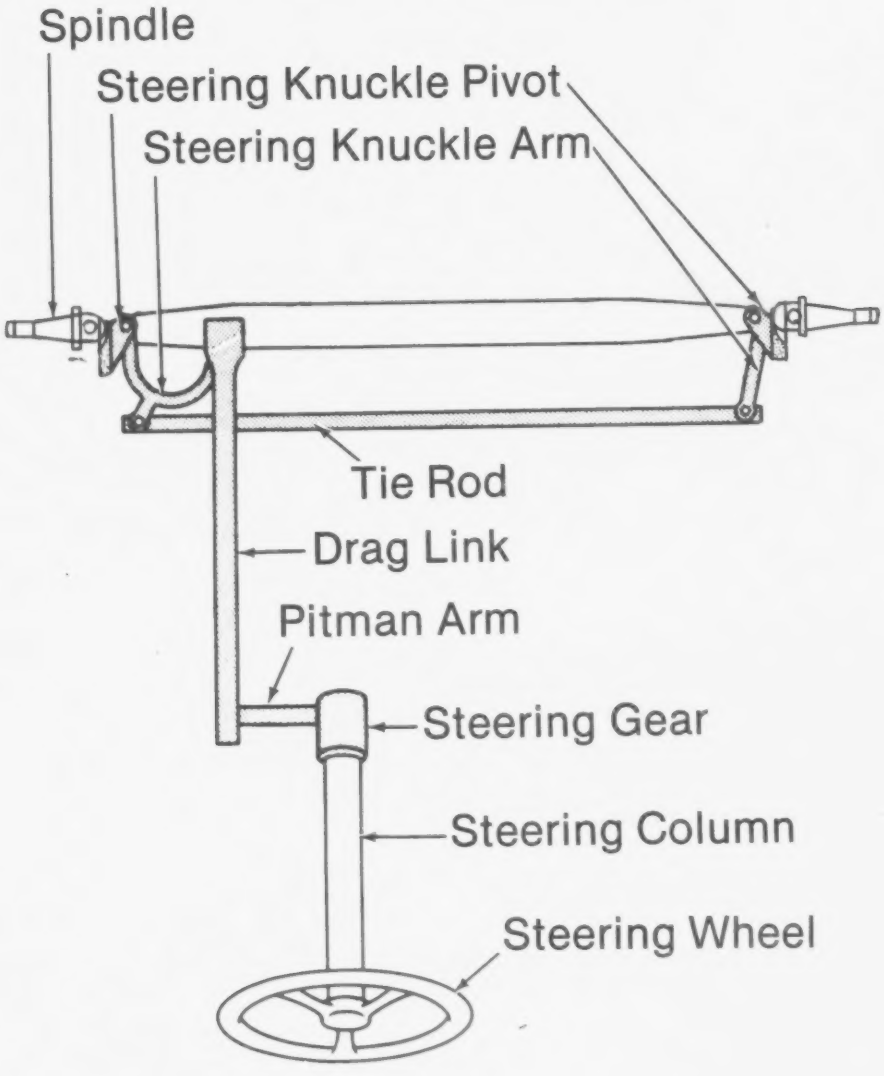
B. Steering column

C. Steering linkage

D. Steering arm

E. Steering knuckle

Mechanical Steering System



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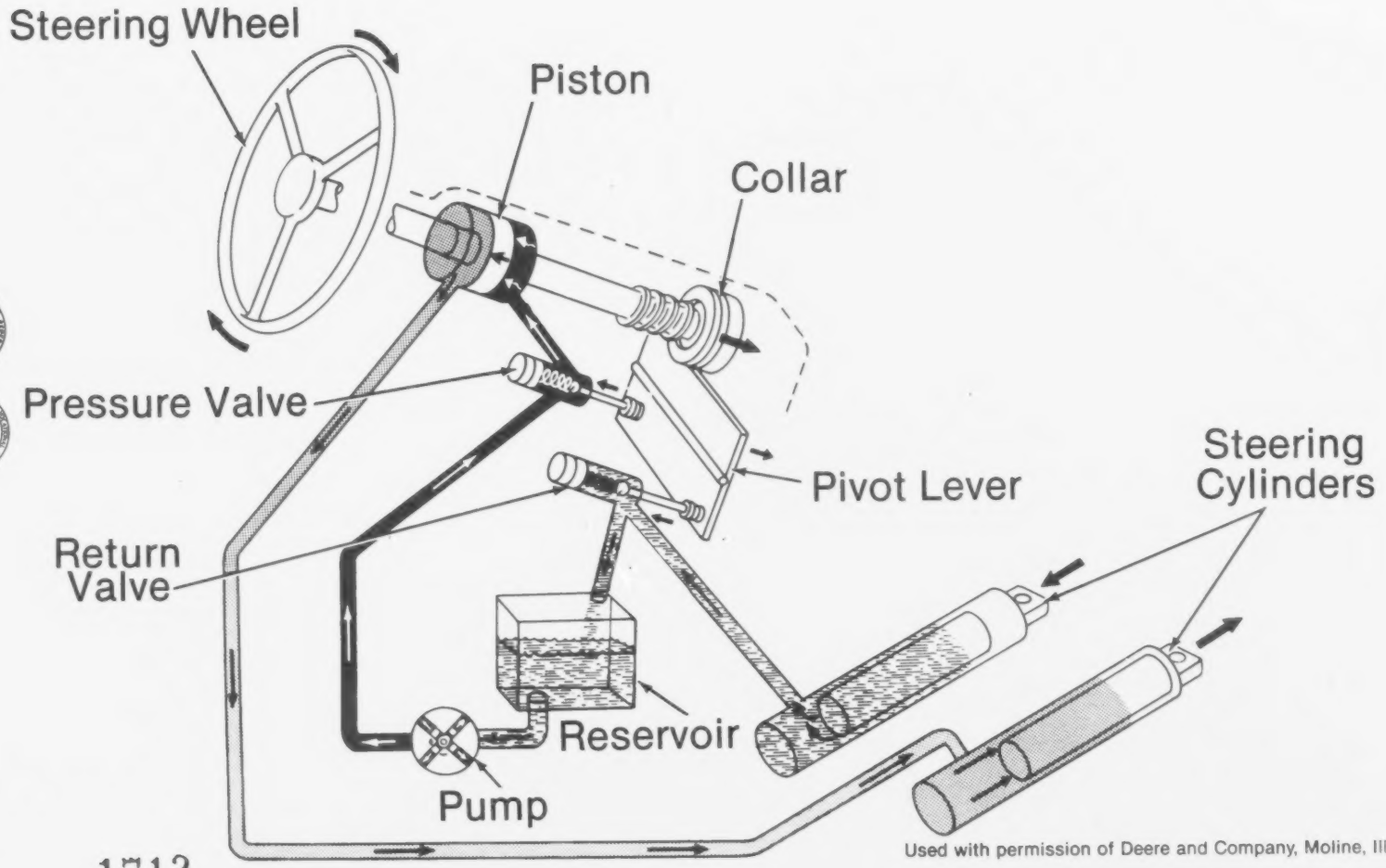
Hydrostatic Steering System



1713

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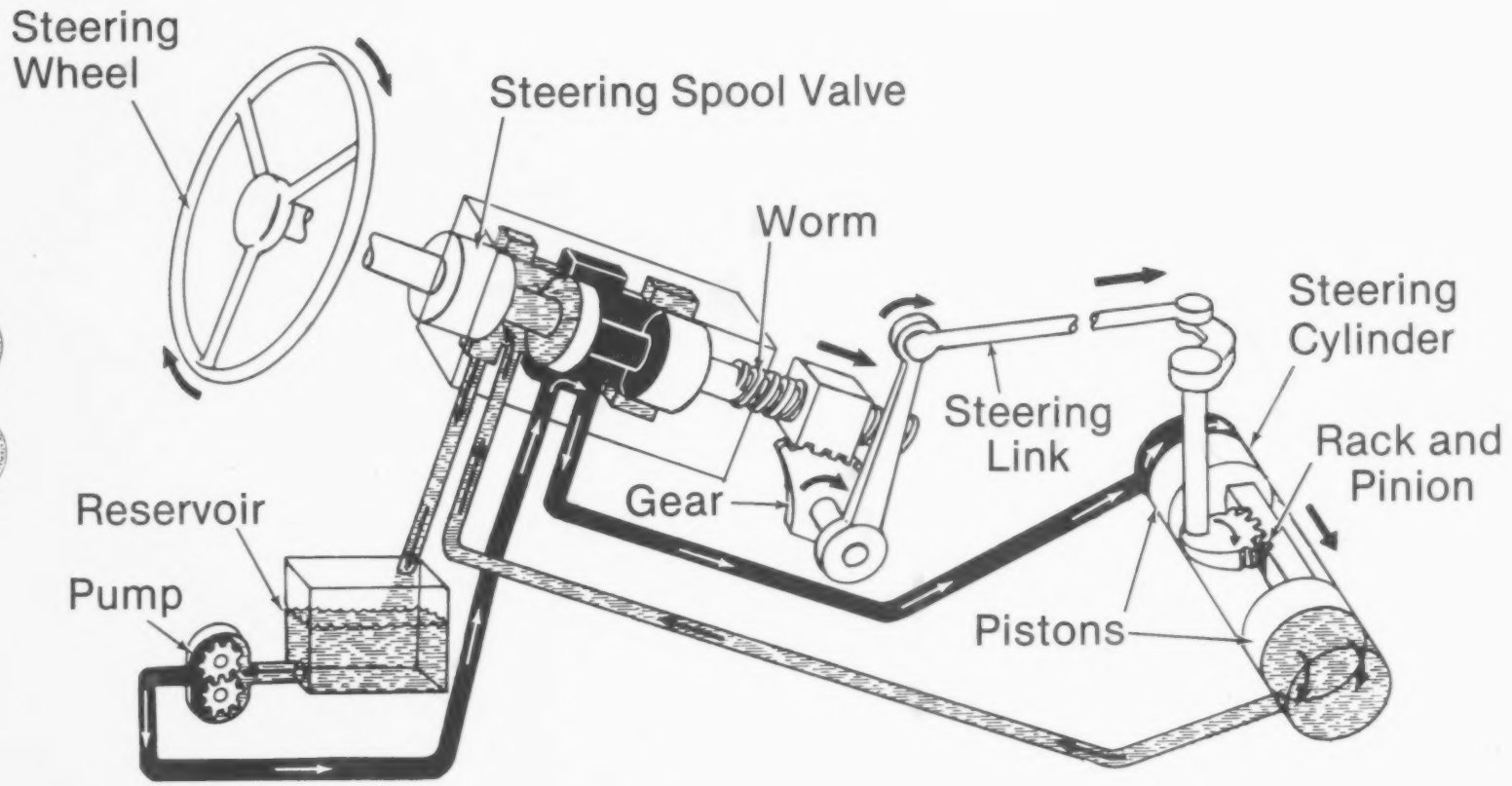
1714

TM #2

HEM - 13-F

Hydraulic Steering System with Mechanical Drag Link



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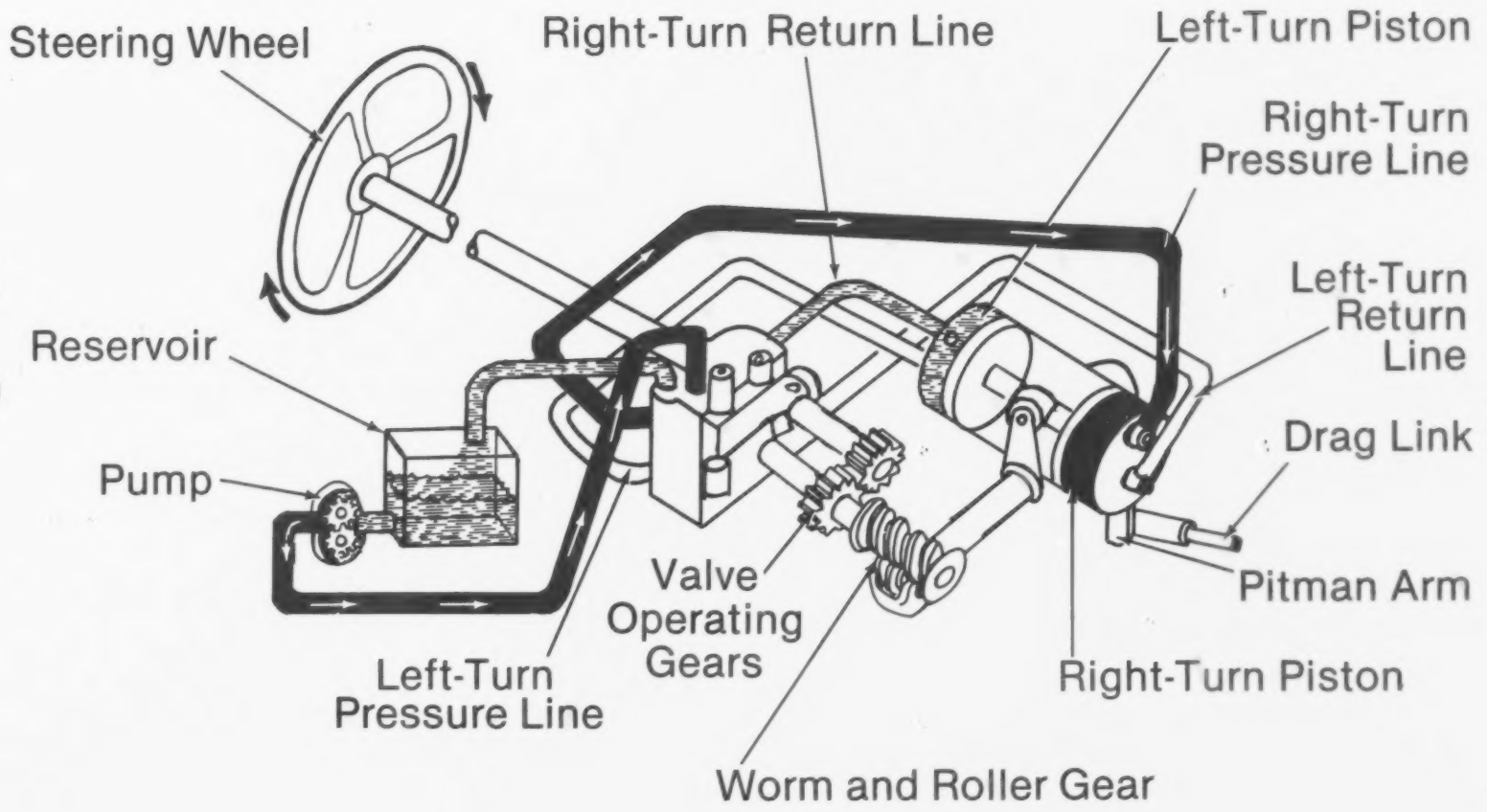
HEM - 15-F

TM #3

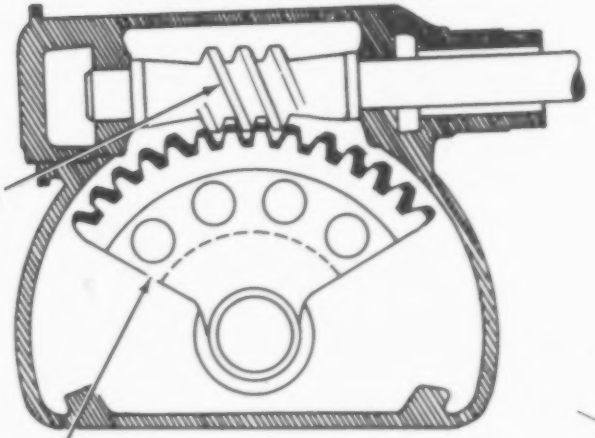
1715

Hydraulic Assist System

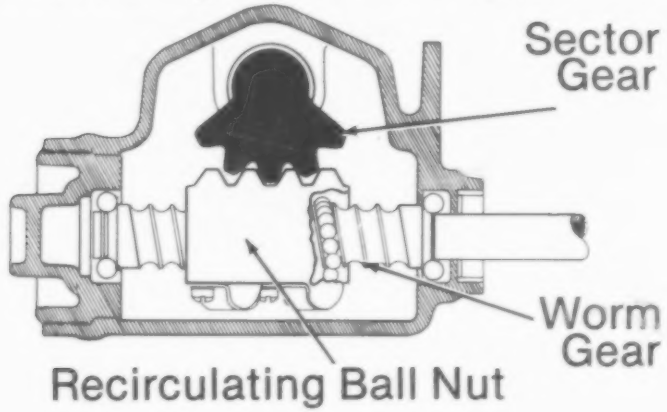


Types of Manual Steering Gears

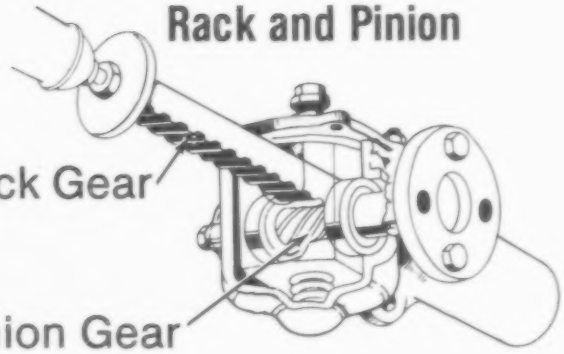
Worm and Sector



Recirculating Ball Nut and Worm



Rack and Pinion



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1720

TM #5

HEM - 19-F

STEERING SYSTEMS
UNIT I

JOB SHEET #1 — INSPECT A STEERING SYSTEM FOR DAMAGED PARTS AND WEAR

I. Equipment and materials

A. Floor jack

B. Jack stands

C. Suitable alignment equipment

D. Dial indicator

E. Shop towels

F. Appropriate service manual

G. Pencil and paper

II. Procedure

A. Inspect steering gear and column adjustment for smooth operation

1. Check steering column mounts for looseness

2. Check steering column alignment with steering gear

3. Check slack in steering shaft coupling, if machine is so equipped, by twisting steering shaft on each side of coupling in opposite directions; watch for slack

4. Raise front of vehicle and support on jack stands close to outer ends of lower control arms

(NOTE: It is important to keep the steering linkage in its normal angle while checking.)

5. Check steering gear mounting bolts for looseness

6. Check pitman arm and retaining nut for looseness

7. Turn steering wheel from one stop to other stop while examining for roughness or catches

(NOTE: On power steering models, run the engine while turning the wheel or checking for slack.

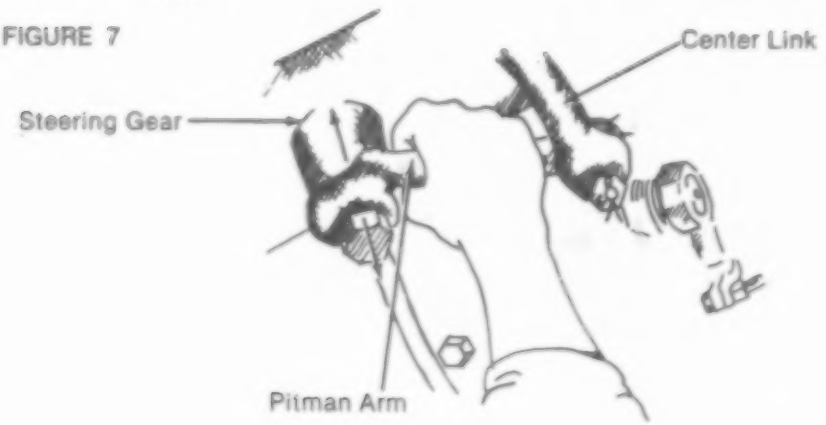
JOB SHEET #1

8. Set steering gear to over-center high point by counting number of turns from one stop to other stop; turn steering wheel back one-half the number of turns

9. Push up and pull down on sector shaft; check for any slack in sector gear lash (Figure 7)

(NOTE: Any indication of slack will require readjustment of the steering gear.)

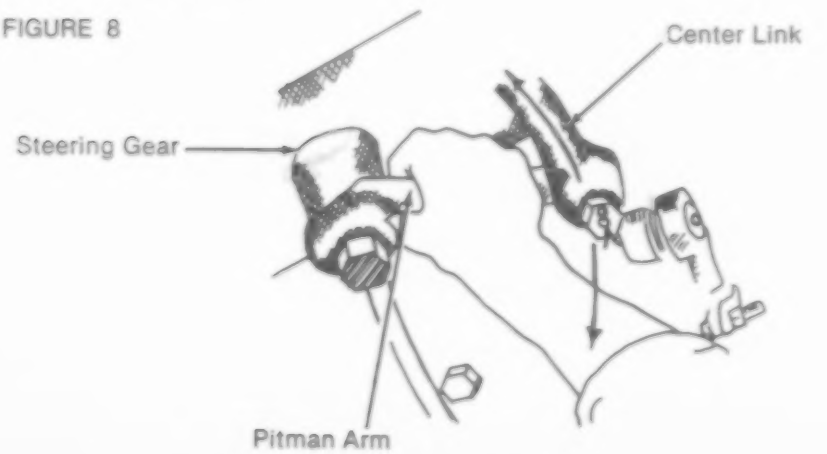
FIGURE 7



10. Pull and push horizontally on pitman arm and feel for slack in worm bearings (Figure 8)

(NOTE: Any indication of slack will require readjustment of the steering gear.)

FIGURE 8



JOB SHEET #1

B. Inspect steering linkage and linkage joints

1. Examine tie rod ends for damaged rubber seals; replace if seals will not repel water

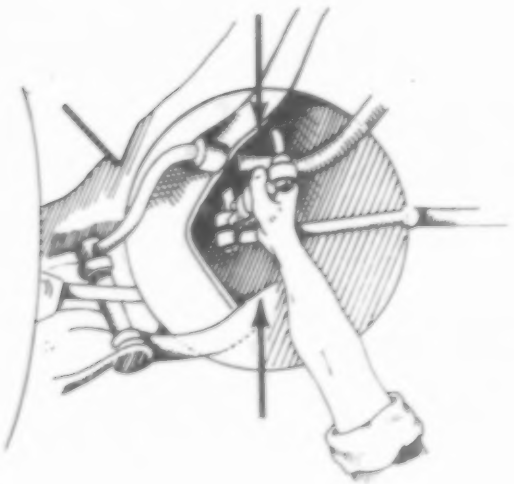
2. Look for any bent linkage or loose attaching bolts

(CAUTION: Do not attempt to straighten steering parts. They are forged metal, and straightening will seriously weaken them. All castellated nuts must be cotter pinned.)

3. Check idler arm by shaking it vertically as hard as you can (Figure 9)

(NOTE: Any excessive vertical looseness produces tire wear, road wander, and erratic steering. Replace the idler arm if excessive vertical looseness is found.)

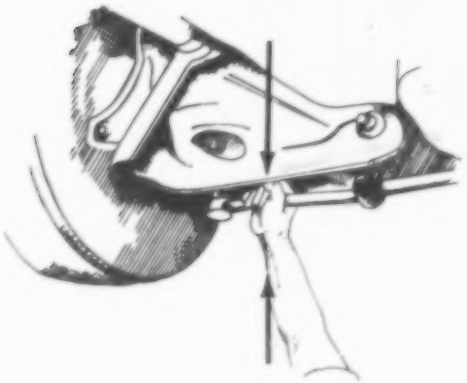
FIGURE 9



4. Check tie rod ends by grasping each tie rod end firmly and shaking with a vertical push-pull movement (Figure 10)

   (NOTE: Tie rod ends should be replaced if any push-pull looseness is observed.)

FIGURE 10



C. Check condition of steering arms

1. Make a preliminary check of steering arms

   a. Measure distance from right steering arm to right wheel rim

   b. Measure distance from left steering arm to left wheel rim

   c. Compare measurements

      (NOTE: The measurements should be within ± 1/8 inch.)

2. Measure turning radius angles

   (NOTE: Toe out on turns for a more accurate check if necessary.)

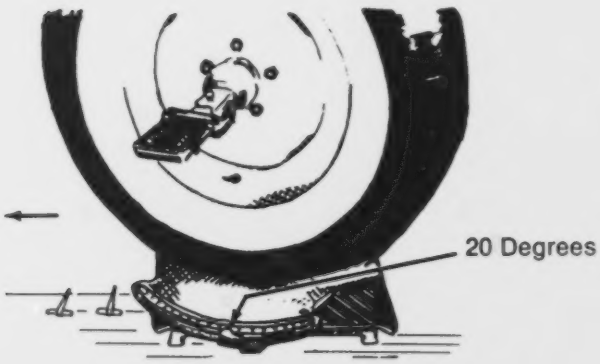
   a. Place front wheels on alignment turntables pointing forward

   b. Set radius gauges at zero

JOB SHEET #1

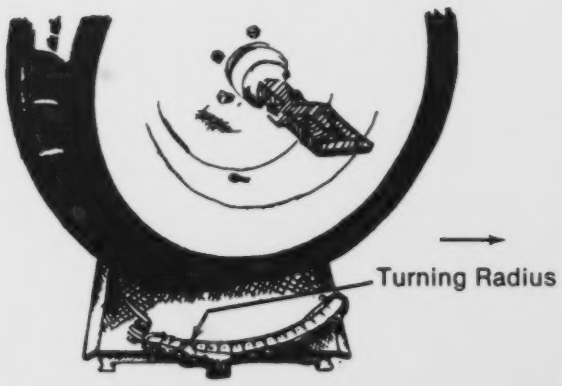
c. Turn left front wheel 20 degrees toward center of vehicle (Figure 11)

FIGURE 11



d. Read right turning-radius gauge scale; record reading (Figure 12)

FIGURE 12



e. Turn right front wheel 20 degrees toward center of vehicle

f. Read left turning-radius gauge scale; record reading

g. Compare readings with manufacturer's specifications

h. Replace steering arm that is not within specified limits

JOB SHEET #1

D. Check steering knuckle and spindle for bent condition

(NOTE: The steering axis inclination angle will indicate a bent condition in the steering knuckle and spindle assembly.)

1. Place front wheels on alignment turntables pointing forward
2. Set turning-radius scales so that gauge pointer reads zero
3. Install caster-camber gauges

   (NOTE: A spindle-mounted gauge is more accurate than a rim-mounted gauge for this reading because wheels tend to roll even though the brakes are locked.)
4. Turn left front wheel toward center of vehicle until turning-radius scale reads 20 degrees
5. Adjust steering axis inclination gauge to zero
6. Turn wheel out from center of vehicle a total 40-degree swing of wheel until turning-radius scale reads 20 degrees
7. Read steering axis inclination on gauge; record reading
8. Turn right front wheel toward center of vehicle until turning-radius scale reads 20 degrees
9. Adjust steering axis inclination gauge until it reads zero
10. Turn wheel out from center of vehicle a total 40-degree swing of wheel until turning-radius scale reads 20 degrees
11. Read steering axis inclination on gauge; record reading
12. Adjust steering axis inclination readings

    a. Add camber reading to steering axis inclination reading if camber is positive

       EXAMPLE: Manufacturer's specifications were 6 degrees at 0 degrees camber; your readings were 5 ½ degrees at ½ degree positive camber; actual steering axis inclination reading is 6 degrees.

JOB SHEET #1

b. Subtract camber reading from steering axis inclination reading if camber is negative

EXAMPLE: Manufacturer's specifications were 6 degrees at 0 degrees camber; your readings were 5 degrees at 3/4 degree negative camber; actual steering axis inclination reading is 4 1/4 degrees.

(NOTE: Some manufacturers do not specify a steering axis inclination angle. On these models, watch for an extreme camber reading such as 2 to 3 degrees above or below specifications, where no suspension wear is evident.)

E. Clean work area; clean and put away all tools and equipment

STEERING SYSTEMS
UNIT I

JOB SHEET #2 — REMOVE AND REPLACE A TIE ROD END

I. Equipment and materials

A. Floor jack

B. Jack stands

C. Basic hand-tool set

D. Tie rod fork

E. Cotter pin for ball stud

F. Ball-peen hammer

G. Penetrating oil

H. Wire brush

I. Shop towels

I. Appropriate service manual

II. Procedure

A. Raise vehicle and place on jack stands

B. Clean threads on tie rod to be replaced

C. Count threads that remain out of adjuster sleeve on tie rod end; record for replacement

D. Soak threads with penetrating oil

E. Loosen adjuster-sleeve clamp bolt

F. Remove cotter pin from ball stud

G. Remove ball stud nut

H. Break joint between ball stud and steering arm eye with tie rod fork and hammer

I. Unscrew tie rod end from adjuster sleeve

JOB SHEET #2

J. Screw new tie rod end into adjuster sleeve until same number of threads are showing as recorded in step C

K. Place ball stud in steering arm eye

L. Install and torque nut on ball stud

M. Install new cotter pin in ball stud

N. Tighten adjuster-sleeve clamp bolt

O. Lower vehicle

P. Remove jack stands and jack

Q. Check toe-in

R. Clean work area; clean and put away all tools and equipment

STEERING SYSTEMS
UNIT I

JOB SHEET #3 — PRESSURE TEST A POWER STEERING SYSTEM

I. Equipment and materials

A. Test gauge with shut-off valve

B. Power steering pressure hose

C. Power steering fluid

D. Basic hand-tool set

E. Thermometer, 0°F to 250°F (–18°C to 125°C)

F. Drain pan

G. Shop towels

H. Appropriate service manual

I. Pencil and paper

II. Procedure

A. Open engine compartment

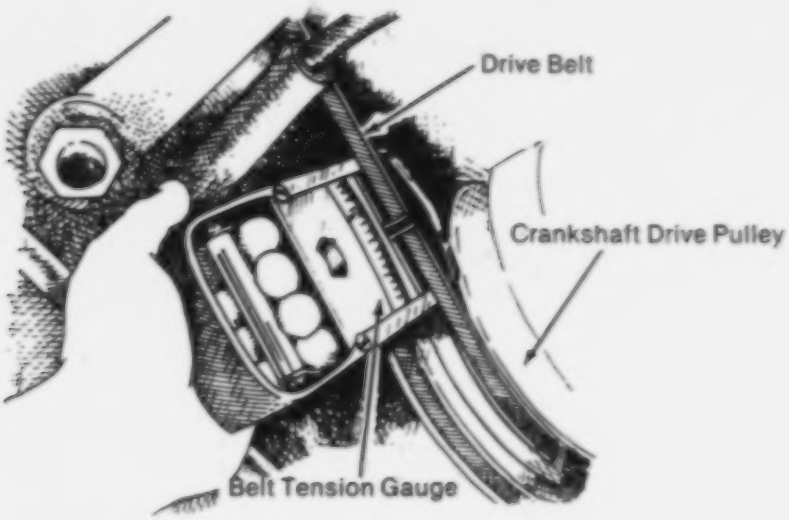
B. Place drain pan under power steering pump area to catch fluid spilled while connecting gauges

JOB SHEET #3

C. Check power steering pump drive belt tension (Figure 13)

(CAUTION: Do not pry against the pump reservoir when adjusting belt tension.)

FIGURE 13

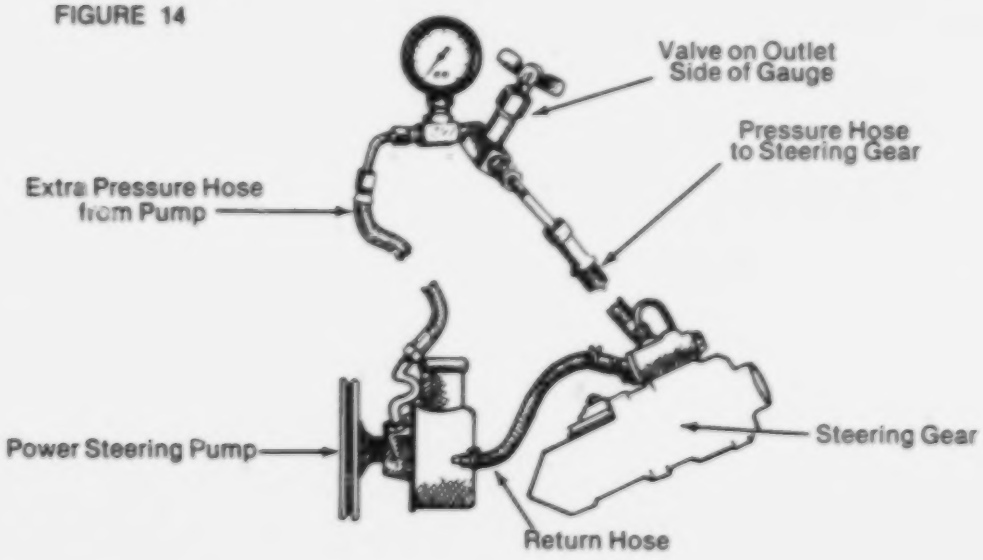


D. Check to be sure that engine is not running; disconnect pressure hose from power steering pump

E. Attach an extra pressure hose to pump and to gauge side of test gauge

F. Connect pressure hose from power steering gear to valve side of test gauge (Figure 14)

FIGURE 14



JOB SHEET #3

G. Add fluid as required to maintain a full pump reservoir

H. Start engine with test valve open

I. Place thermometer in reservoir fill tube

J. Operate engine and power steering until fluid temperature is 150°F to 170°F (66°C to 77°C)

K. Record pressure at idle speed with valve open

L. Close valve and take pressure reading

(CAUTION: To protect the pump from damage, do not leave the valve closed for more than five seconds.)

M. Compare reading with specifications for pump; repair pump if readings are 100 pounds per square inch (psi) or lower than specifications

N. Hold steering wheel against each stop just long enough to obtain pressure reading; record pressure readings

(NOTE: These pressures should be within 50 psi of each other and within 50 psi of specifications. If the pressures are off, it will be necessary to make internal repairs on the steering gear.)

O. Turn off engine

P. Remove test gauge

Q. Make necessary repairs

R. Clean work area; clean and put away all tools and equipment

STEERING SYSTEMS
UNIT I

JOB SHEET #4 — REMOVE, RESEAL, AND REPLACE
A POWER STEERING PUMP

I. Equipment and materials

A. Power steering pump and accessories

B. Basic hand-tool set

C. Power steering fluid

D. Plastic-tipped hammer

E. Shaft-seal puller

F. Shaft-seal driver

G. Shaft-seal protector

H. Drive-pulley puller

I. Block of wood, 2" × 2" × 6"

J. Drain pan

K. Shop towels

L. Appropriate service manual

II. Procedure

A. Open engine compartment

B. Remove power steering hoses at pump

C. Drain fluid from pump into drain pan

D. Plug hose ends to prevent foreign material from entering system

E. Remove drive belt

F. Remove mounting bolts from pump

G. Remove power steering pump

(NOTE: Be sure to empty the remaining fluid from the pump.)

JOB SHEET #4

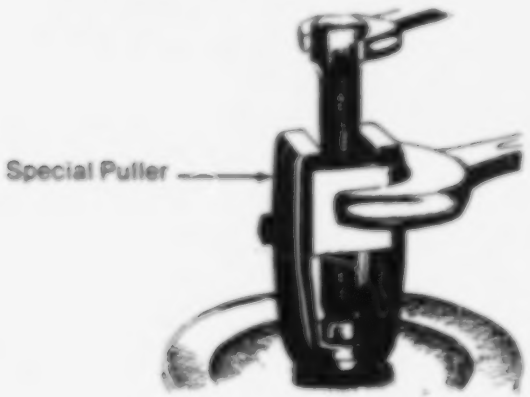
H. Remove any support parts remaining on pump

I. Remove drive pulley retaining nut if engine is so equipped

J. Use puller to remove pulley (Figure 15)

(CAUTION: Do not hammer or pry on pulley.)

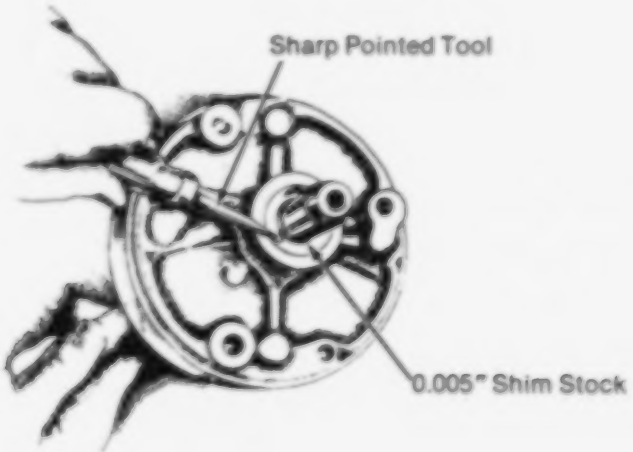
FIGURE 15



K. Remove shaft seal

(NOTE: If a puller is not available, wrap the shaft with shim stock for protection. Pierce the seal with a sharp punch and then pry it out. See Figure 16.)

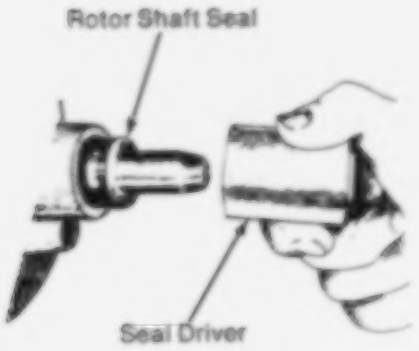
FIGURE 16



JOB SHEET #4

L. Replace seal, driving new seal squarely into seal seat with a driver (Figure 17)

FIGURE 17



M. Remove reservoir retaining bolts and fluid outlet union

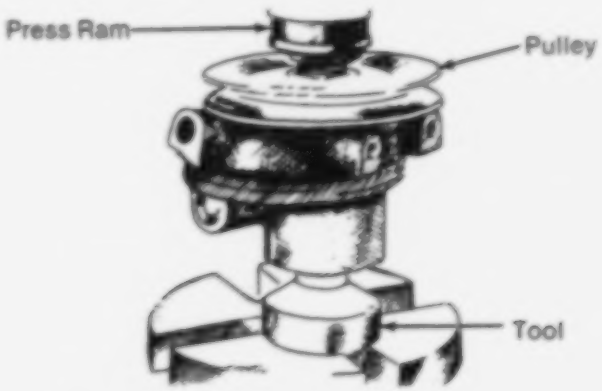
N. Remove reservoir by tapping lightly on rim

O. Wash reservoir in solvent; air dry

(NOTE: Replace the press-on type drive pulley before installing the reservoir.)

(CAUTION: Support the bottom of the shaft while pressing the pulley on. See Figure 18.)

FIGURE 18



JOB SHEET #4

Q. Install new seals into clean seal recesses in pump body

R. Lubricate reservoir seal surface with power steering fluid

S. Place reservoir on pump body with holes in reservoir aligned with pump holes

T. Lay small wooden block across reservoir; tap reservoir into place

(CAUTION: Protect the pump shaft from sharp blows or heavy axial force.)

U. Replace and torque retainer bolts and fluid union

V. Replace drive pulley; torque retaining nut if vehicle is so equipped

W. Replace any pump mounts or accessories removed earlier

X. Install pump on vehicle

Y. Place drive belt on pulley

Z. Tighten belt to specified tension

(CAUTION: Do not move the pump by prying on the reservoir or pulling on the filler neck.)

AA. Reconnect hoses

(NOTE: Align the hoses as they are tightened so that they will not be damaged during operation.)

BB. Fill pump reservoir with power steering fluid

CC. Bleed air from system by starting engine and stopping it after a few seconds, adding fluid as needed; repeat three or four times

DD. Start engine; turn steering wheel to each side stop and hold for two seconds; turn off engine

EE. Check fluid level

FF. Recheck for any fluid leaks

GG. Road test with instructor

HH. Recheck for fluid leaks

II. Clean work area; clean and put away all tools and equipment

STEERING SYSTEMS
UNIT I

TEST

NAME _____ SCORE _____

1. Match to their correct definitions terms associated with steering systems. Write the correct numbers in the blanks.

_____a.	System of gears and linkage in vehicle that permits driver to turn wheels for changing direction of travel	1. Caster
_____b.	Part of steering system located at lower end of steering column; transfers rotary motion of steering wheel to vehicle wheels	2. Camber
_____c.	Number of degrees that steering knuckle pivots are tilted forward or backward from the vertical when viewed from the side	3. Castellated nut
_____d.	Difference in turning ratios of wheels when turning	4. Toe-in
_____e.	Linkage between steering gear and vehicle wheels	5. Over-center high point
_____f.	Angle of wheel with the vertical when it is in straight-ahead position	6. Steering gear
_____g.	Amount in inches that wheels point in; distance between front of wheels is less than distance between rear of wheels	7. Kingpin inclination
_____h.	Number of degrees that steering knuckle pivots are tilted sideways toward center of vehicle	8. Wheel alignment
_____i.	Hex-shaped nut with slots that line up with hole in shaft or spindle so that cotter pin can be inserted to lock nut in place	9. Steering linkage
_____j.	Mechanics of keeping all parts of steering system properly adjusted	10. Steering system
_____k.	Gear tooth mesh at its closest tolerance at center of worm and sector gear travel	11. Toe-out

TEST

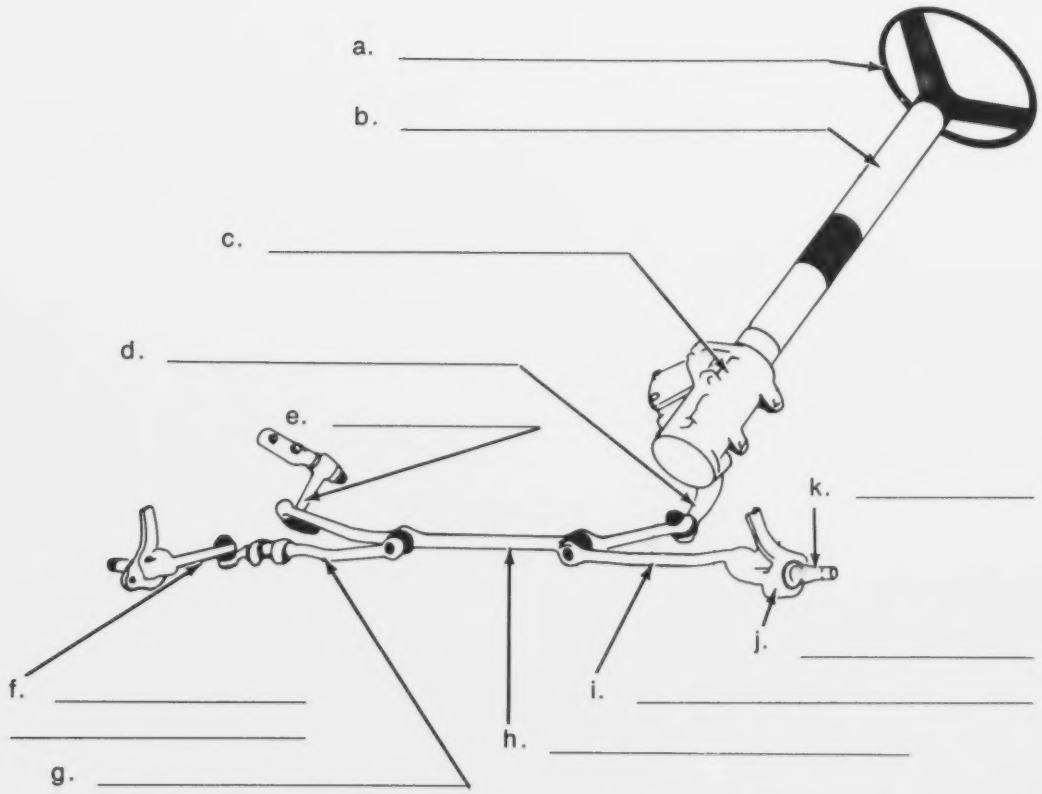
2. Name major types of steering systems.

   a. _____

   b. _____

   c. _____

3. Label basic parts of the steering system illustrated below.



TEST

4. Name types of manual steering gears.

   a. _____

   b. _____

   c. _____

5. List factors involved in steering a conventional or crawler tractor.

   a. _____

   b. _____

   c. _____

   d. _____

6. List wheel alignment angles.

   a. _____

   b. _____

   c. _____

   d. _____

   e. _____

7. Match wheel alignment angles to their correct functions. Write the correct numbers in the blanks.

_____a.	Aids steering stability and establishes a pivot point about which the wheel can be easily turned	1. Toe-in
_____b.	Enables front wheels to maintain a straight-ahead position after a turn has been completed	2. Kingpin inclination
_____c.	Allows inner front wheel to roll freely on turns, and prevents outer wheel from dragging	3. Toe-out
_____d.	Compensates for varying tolerances in the steering linkage, and prevents excessive tire wear	4. Camber
_____e.	Brings road contact point of tire more nearly under point of load, and eliminates excessive tire wear	5. Caster

TEST

8. Select from the following list results of improper wheel alignment. Write an "X" in the blank before each correct answer.

   _____a. Vehicle rides better

   _____b. Steering may be hard or erratic

   _____c. Tires wear longer

   _____d. Vehicle shimmies

   _____e. Vehicle wanders

   _____f. Vehicle holds to a straight line

9. List four steering parts that should be inspected for wear, adjustment, and damage.

   a. _____

   b. _____

   c. _____

   d. _____

(NOTE: Test question 10 lists the job sheets. They are an important part of this test. If they have not been completed, check with your instructor.)

10. Demonstrate the ability to

    a. Inspect a steering system for damaged parts and wear.

    b. Remove and replace a tie rod end.

    c. Pressure test a power steering system.

    d. Remove, reseal, and replace a power steering pump.

STEERING SYSTEMS
UNIT I

ANSWERS TO TEST

1. a. 10 e. 9 i. 3
   b. 6 f. 2 j. 8
   c. 1 g. 4 k. 5
   d. 11 h. 7

2. a. Mechanical (manual)
   b. Power
   c. Hydraulic assist

3. a. Steering wheel
   b. Steering column
   c. Steering gear
   d. Pitman arm
   e. Idler arm
   f. Steering arm
   g. Tie rod
   h. Center link or relay link
   i. Tie rod
   j. Steering knuckle
   k. Steering spindle

4. a. Recirculating ball nut and worm
   b. Worm and sector
   c. Rack and pinion

5. a. Steering clutches
   b. Steering brakes
   c. Footing
   d. Load being pulled or pushed

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ANSWERS TO TEST

6. a. Toe-out
   b. Caster
   c. Camber
   d. Kingpin (steering axis) inclination
   e. Toe-in

7. a. 2
   b. 5
   c. 3
   d. 1
   e. 4

8. b, d, e

9. Answer should include any four of the following
   a. Steering gear
   b. Steering column
   c. Steering linkage
   d. Steering arm
   e. Steering knuckle

10. Performance skills evaluated to the satisfaction of the instructor

TIRES
UNIT II

UNIT OBJECTIVE

After completing this unit, the student should be able to demount, repair, and mount tires. The student will show this knowledge by completing job sheets and unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match to their correct definitions terms associated with tires.
2. Identify the parts of a tire.
3. Label ply construction of tires.
4. Explain the meaning of numbers and arrows on tire sidewall.
5. Describe overinflation, underinflation, and proper inflation.
6. Name factors that determine amount of ballast to use on equipment.
7. Discuss travel reduction.
8. Name materials used for wheel ballast.
9. List advantages of dual tires.
10. List causes of tire failure.
11. State safety rules to observe when demounting, inflating, or mounting tires.
12. Demonstrate the ability to
    a. Demount a tube-type tire.
    b. Mount a tube-type tire.
    c. Demount a tubeless tire.
    d. Mount a tubeless tire.
    e. Repair a tire.

TIRES
UNIT II

SUGGESTED ACTIVITIES

I. Suggested activities

A. Order films and other materials to supplement unit.

(NOTE: Manufacturers and dealers are the best sources for these materials.)

B. Gather equipment and materials for job sheet demonstrations.

C. Obtain transparencies.

(NOTE: Transparencies are available from AGC and CIMC.)

D. Provide students with objective sheet.

E. Discuss unit and specific objectives.

F. Provide students with information and job sheets.

G. Discuss information sheet.

H. Emphasize importance of safety when inflating and mounting tires.

I. Demonstrate and discuss procedures outlined in the job sheets.

J. Give test.

K. Complete appropriate section of competency profiles.

(NOTE: Competency profiles are available from AGC and CIMC.)

II. Instructional materials

A. Objective sheet

B. Suggested activities

C. Information sheet

D. Transparency masters

1. TM #1 — Standard Industry Code of Tire Types

2. TM #2 — Meanings of Numbers and Directional Arrows

SUGGESTED ACTIVITIES

3. TM #3 — Tire Inflation
4. TM #4 — Proper Matching of Rim Parts
5. TM #5 — Approved Rim Contours

E. Job sheets

1. Job Sheet #1 — Demount a Tube-Type Tire
2. Job Sheet #2 — Mount a Tube-Type Tire
3. Job Sheet #3 — Demount a Tubeless Tire
4. Job Sheet #4 — Mount a Tubeless Tire
5. Job Sheet #5 — Repair a Tire

F. Test

G. Answers to test

III. Unit reference — *Fundamentals of Service: Tires and Tracks*, 5th Ed. Moline, Illinois: Deere and Company, 1980.

TIRES
UNIT II

INFORMATION SHEET

I. Terms and definitions

A. Ballast — Weight added to tire or wheel to produce better traction and drawbar pull

B. Bead — Bundles of wire that form the tire foundation to which all tire plies are tied; anchors tire to rim and prevents changes of fit on rim

C. Body plies — Layers of rubber-cushioned cord or fabric insulated from the next layer of the same compound; hold in the inflation pressure that supports load and cushions shock

D. Calcium chloride — Salt-like agent used to prevent water from freezing when water is used as ballast inside a tire

E. Deflate/deflation — Process of removing air pressure from a tire; state of being deflated

F. Flex — To stretch or bend

G. Flotation — Act, process, or state of floating; ability to stay on the surface of soft ground or snow

H. Inflate/inflation — Process of putting air into a tire; state of being inflated

I. Ply rating — Strength of tire; identifies a given tire with its recommended load when used for a specific type of service

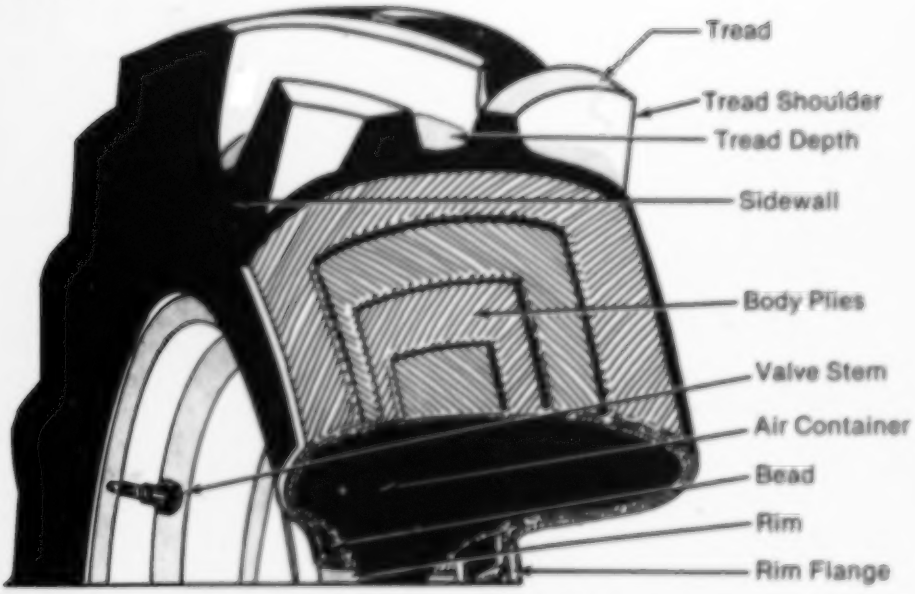
J. Rim — Outer part of wheel that supports the tire

K. Travel reduction — Percentage of slip of the drive wheels

INFORMATION SHEET

II. Parts of a tire (Figure 1)

FIGURE 1

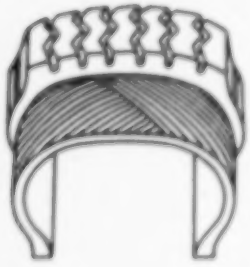


Source: *FOS Tires and Tracks*, Deere and Company, Moline, Illinois.

III. Ply construction of tires (Figures 2-5)

A. Bias

FIGURE 2

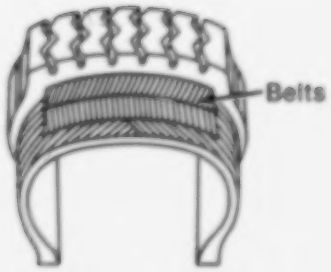


Used with permission of Deere and Company, Moline, Illinois.

INFORMATION SHEET

B. Belted bias

FIGURE 3



Used with permission of Deere and Company, Moline, Illinois.

C. Belted radial

FIGURE 4

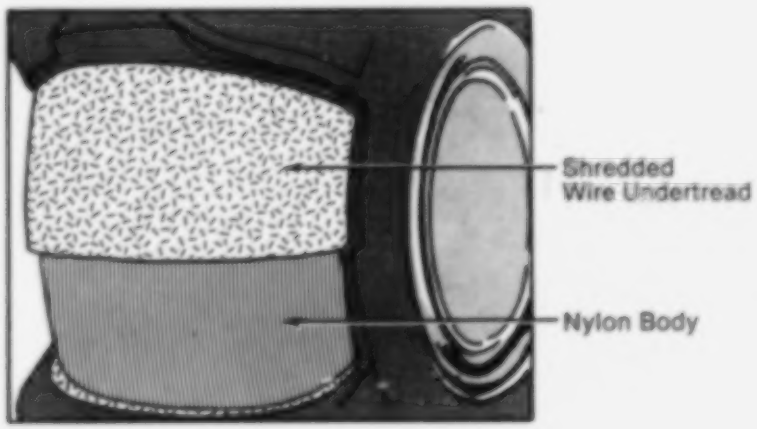
Used with permission of Deere and Company, Moline, Illinois.

INFORMATION SHEET

(NOTE: In some large tires a layer of wire is cured between the tread and body of the tire. This protective layer of wire keeps most cuts from penetrating into the body, keeps tread cuts from growing, and holds tread cuts closed so that sand and dirt do not enter and cause separation. See Figure 5.)

EXAMPLE:

FIGURE 5

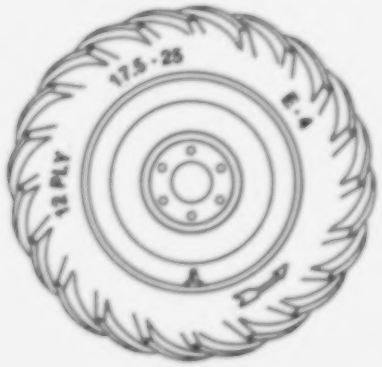


Source: *FOS Tires and Tracks*, Deere and Company, Moline, Illinois.

IV. Meaning of numbers and arrows on tire sidewall (Figure 6; Transparencies #1 and #2)

EXAMPLE:

FIGURE 6



Adapted with permission of Deere and Company, Moline, Illinois.

INFORMATION SHEET

A. E-4 -- Denotes that tire is industrial off-the-road type with a rock-deep tread

B. 25 — Indicates nominal diameter of rim in inches

C. 17.5 — Indicates section width of tire in inches when mounted on its recommended rim

D. 12 ply — Identifies recommended load when tire is used in a specific type of service; tells strength of tire

(NOTE: At one time, ply rating told the actual number of plies in the body of the tire.)

E. Arrow — Indicates forward rotation of drive-wheel tires

(NOTE: Drive-wheel tires on some equipment must be mounted to rotate in a certain direction for best traction.)

V. Tire inflation (Transparency #3)

(NOTE: Tires are designed to operate at certain inflations that provide normal flexing with proper deflection and road contact. Overinflation can be as serious as underinflation. Both can result in high tire damage and high fuel costs.)

A. Overinflation -- Tire is too rigid and can be damaged by impacts; prevents full contact of tire with ground; causes excessive wear at center of tread

B. Underinflation — Too much tread contacts ground; tires flex too much and heat up; causes excessive wear on sides of tread

C. Proper inflation — Provides full tread contact with ground; ensures proper traction and flotation; prevents too much or too little flexing

VI. Factors that determine amount of ballast to use on equipment

A. Type of equipment and job it is performing

B. Soil surface

C. Equipment power output

D. Travel speed

E. Tires

INFORMATION SHEET

VII. Travel reduction

A. Under normal conditions, slip should be about 10 to 15 percent; zero slip is not good

B. If less than 10 percent slip, remove weight; if more than 15 percent slip, add more weight

(NOTE: Horsepower is reduced considerably when drive wheels slip too much or too little.)

VIII. Materials used for wheel ballast

A. Liquid

(NOTE: Liquid ballast is usually water containing calcium choride. The drive-wheel tire tube is filled only 75 percent with this liquid.)

B. Cast iron

(NOTE: Cast iron ballast consists of disc-shaped weights installed on the drive wheels.)

C. Dry powder

(NOTE: Dry ballast is a powder that is added to the drive-wheel tire. The tire is normally filled 87 to 95 percent full.)

IX. Advantages of dual tires

A. Provide more ground contact, thus reduce slippage, increase ground speed, improve work rates, and possibly lessen fuel consumption

B. Provide improved machine stability

C. Provide a smooth ride, thus help prevent driver fatigue

D. Provide more flotation, thus help keep machine on top of ground

E. Have better potential for all-season use

F. Permit use of equipment under adverse weather and soil conditions

G. Permit a machine with one tire requiring service to be moved to a convenient place for repairs

(NOTE: When installing dual tires, proper matching is important. For instance 9.00-20 tires from different manufacturers have different diameters.)

INFORMATION SHEET

X. Causes of tire failures

A. Fabric break

B. Rubber checks

C. Wear from spinning wheels

D. Bruises

E. Valve damage

F. Tread and sidewall cuts

G. Grease and oil damage

H. Obstructions (frame or fender rubbing tire)

XI. Safety rules to observe when demounting, inflating, or mounting tires

(CAUTION: An inflated tire and the rim on which it is mounted can be very dangerous. Under pressure, the tire packs the explosive force of TNT.)

A. Follow proper procedures and manufacturer's recommendations

B. Block wheels on other side of vehicle before placing jack in position

C. Always use a wood block under jack when working on the ground

D. Never attempt to unseat beads of an inflated tire; remove valve core and exhaust ALL air pressure before removing a tire

E. Deflate tires on multipiece wheels before removing the wheel

F. Do not attempt to inflate or repair tires without proper tools

G. Never stand in front of, or over tire when inflating

H. Always use a clip-on chuck and extension hose when inflating tires

I. Use an inflation cage whenever possible

J. Keep hands and feet away from pinch points when using bead breakers and other tire tools

K. Never attempt to lift or move heavy tires and wheels without help; use a cable or chain sling if necessary

L. Handle tire and wheel or rim assemblies carefully

INFORMATION SHEET

M. When seating tire beads on rim, never exceed maximum inflation pressure

N. Never start to inflate a tapered-bead tire unless the bead-seat band has been pried out over the lock ring

O. Always match rim parts properly (Transparencies #4 and #5)

(NOTE: Most rims look alike, but all vary slightly in design. These variations among rims make mixing rim parts very hazardous. A close, proper fit between rim parts is essential to long tire life as well as operating safety.)

P. Always keep a firm grip on tire irons and tools

Q. Carefully clean all dirt from lock ring gutter to allow gutter to fit securely in its proper position

R. Never attempt to rework, weld, heat, or braze wheel parts; instead, always replace them with new parts

S. Never transport a fully inflated tire; inflate tire only after tire and rim assembly have been mounted

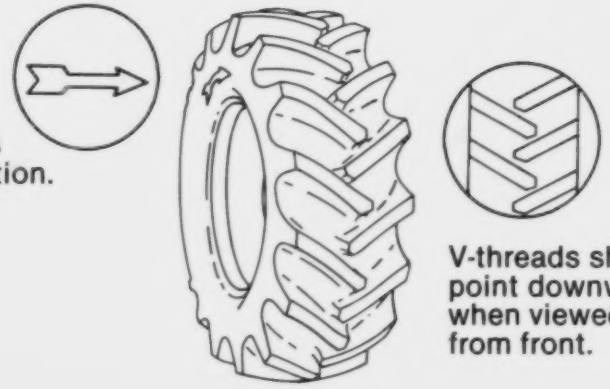
Standard Industry Codes for Tire Types

TYPE OF TIRE	CODE
Front Tractor	
Rice tread	F-1
Single-rib tread	F-2
Dual-rib tread	F-2D
Triple-rib tread	F-2T
Industrial tread	F-3
Drive-Wheel Tractor (Rear)	
Rear wheel, regular tread	R-1
Cane and Rice, deep tread	R-2
Shallow, nondirectional tread	R-3
Industrial, intermediate tread	R-4
Implement	
Rib tread	I-1
Traction tread	I-3
Plow tail wheel	I-4
Smooth tread	I-6
Off-the-Road Tires (Industrial)	
Rib	E-1
Traction	E-2
Rock	E-3
Rock deep tread	E-4
Rock intermediate	E-5
Rock maximum	E-6
Flotation	E-7

Also includes similar treads for "G," "L," and "ML" series codes.

1754

Meanings of Numbers and Directional Arrows



Arrow shows forward rotation.

V-threads should point downward when viewed from front.

Used with permission of Deere and Company, Moline, Illinois.

Tire Inflation

Overinflation | Underinflation | Proper Inflation

Used with permission of Deere and Company, Moline, Illinois.

TM #3

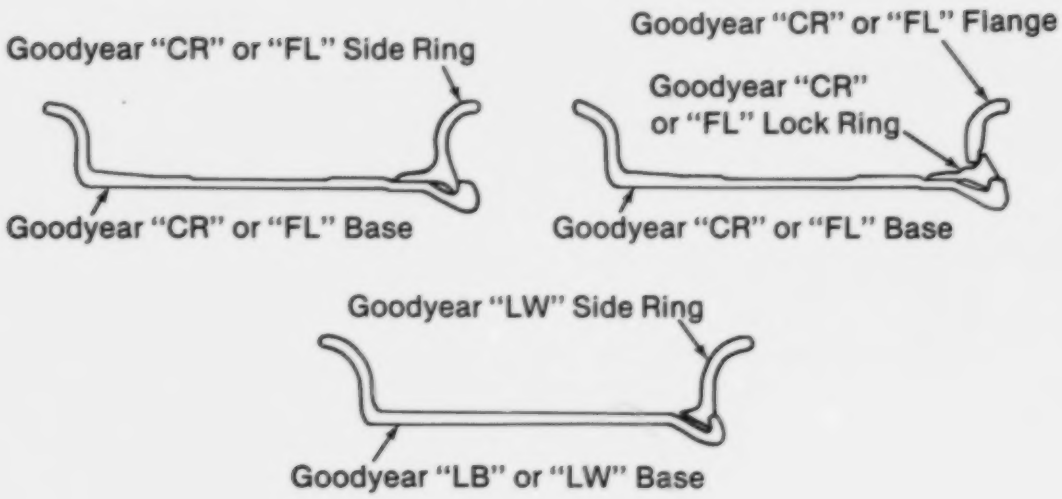
1757

1758

HEM - 61-F

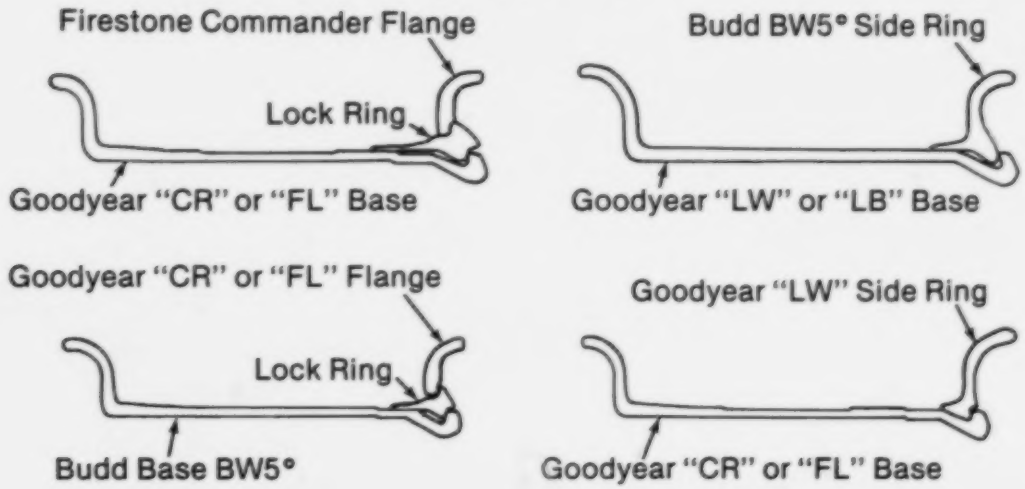
Proper Matching of Rim Parts

Correct


Goodyear "CR" or "FL" Side Ring
Goodyear "CR" or "FL" Base
Goodyear "CR" or "FL" Flange
Goodyear "CR"
or "FL" Lock Ring
Goodyear "CR" or "FL" Base
Goodyear "LW" Side Ring
Goodyear "LB" or "LW" Base

Goodyear "CR" and "FL" Bases and Components Interchangeable with Firestone "CR" and "FL"

Incorrect



WARNING! MISMATCHED RIM PARTS ARE DANGEROUS.

Used with permission of The Goodyear Tire and Rubber Company.

1759

Approved Rim Contours

APPROVED RIM CONTOURS FOR
TIRES FOR TRUCKS, BUSSES, AND TRAILERS
USED IN NORMAL HIGHWAY SERVICE
(TABLES TB-1B and TB-1R)

Tire Size Designation		Approved Rim Contours
Diagonal (Bias) Ply	Radial Ply	
7.50-15 TR	7.50R15 TR	6.5, 6.50T
		6.0, 6.00S
7.50-17	7.50R17	6.5, 6.50T
		6.0, 6.00S
7.50-18	7.50R18	6.5, 6.50T
		6.0, 6.00S
7.50-20	7.50R20	6.5, 6.50T
		6.0, 6.00S
8.25-15 TR	8.25R15 TR	7.0, 7.00T, 7.0T 5°
		6.5, 6.50T
8.25-17	8.25R17	7.0, 7.00T, 7.0T 5°
		6.5, 6.50T
8.25-20	8.25R20	7.0, 7.00T, 7.0T 5°
		6.5, 6.50T

Tire Size Designation		Approved Rim Contours
Diagonal (Bias) Ply	Radial Ply	
9.00-15 TR	9.00R15 TR	7.5, 7.50V
		7.0, 7.00T, 7.0T 5°
9.00-20	9.00R20	7.5, 7.50V
		7.0, 7.00T, 7.0T 5°
10.00-15 TR	10.00R15 TR	8.0, 8.00V, 8.0V 5°
		7.5, 7.50V
10.00-20	10.00R20	8.0, 8.00V, 8.0V 5°
		7.5, 7.50V
10.00-22	10.00R22	8.0, 8.00V, 8.0V 5°
		7.5, 7.50V
11.00-15 TR	11.00R15 TR	8.5, 8.50V, 8.5V 5°
		8.0, 8.00V, 8.0V 5°
11.00-20	11.00R20	8.5, 8.50V, 8.5V 5°
		8.0, 8.00V, 8.0V 5°
11.00-22	11.00R22	8.5, 8.50V, 8.5V 5°
		8.0, 8.00V, 8.0V 5°
11.00-24	11.00R24	8.5, 8.50V, 8.5V 5°
		8.0, 8.00V, 8.0V 5°
12.00-20	12.00R20	9.00V
		8.5, 8.50V, 8.5V 5°
12.00-24	12.00R24	9.00V
		8.5, 8.50V, 8.5V 5°

NOTE: New-tire section widths will change .20 inches for each ½-inch change in rim width.

1760

TIRES
UNIT II

JOB SHEET #1 — DEMOUNT A TUBE-TYPE TIRE

I. Equipment and materials

A. Mounted tube-type tire

B. Heavy-duty jack

C. Tire tools and irons

D. Wheel blocks

E. Axle stand

F. Small jack

G. Small piece of stiff wire

H. Piece of pipe to fit over straight end of tire tool

II. Procedure

(CAUTION: Failure to comply with these procedures may result in faulty placement of the tire or rim, which could cause the assembly to explode with sufficient force to cause serious injury or death.)

A. Block all wheels securely, except the one being changed

B. Place jack; jack up wheel until tire is clear of ground

C. Place axle stand under axle; then let jack down just enough so that weight of machine is on stand and jack

D. Lock wheel by putting vehicle into gear with valve at top of tire

E. Remove valve core, and exhaust ALL air pressure from tire

F. Run a wire through the valve stem to make sure that valve is not plugged

G. Remove rim nut, and push valve through valve hole

JOB SHEET #1

H. Place flat, hooked end of tire tool near valve hole in one of the breaking slots between seat band and rim flange (Figure 7)

FIGURE 7

Source: *FOS Tires and Tracks*, Deere and Company, Moline, Illinois.

I. Slip piece of pipe over straight end of tire tool (for leverage), and twist tool in a circular direction (Figure 8)

FIGURE 8

Source: *FOS Tires and Tracks*, Deere and Company, Moline, Illinois.

J. Hold this position while another person inserts another tire tool between bead seat and side flange

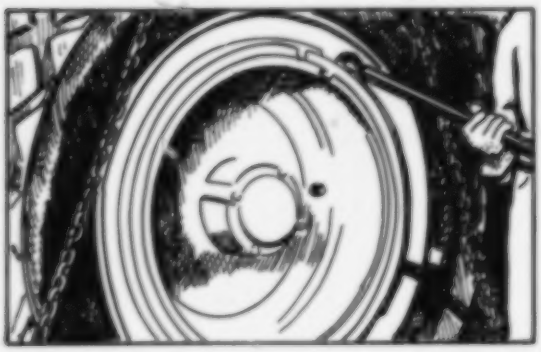
K. Use the same circular twisting motion to hold amount of space gained with first tool

L. Move first tool forward around rim

JOB SHEET #1

M. Twist and follow up with second tool (Figure 9)

FIGURE 9



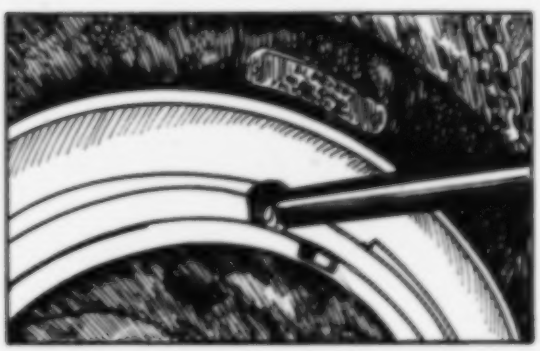
Source: *FOS Tires and Tracks*, Deere and Company, Moline, Illinois.

N. Continue around bead-seat band until outer bead is loose

O. Start bead-seat band away from lock ring

1. Place tool in gutter section between ends of lock ring
2. Pry radially with tool (Figure 10)

FIGURE 10



Source: *FOS Tires and Tracks*, Deere and Company, Moline, Illinois.

P. Using both tools as in steps L and M, work completely around rim

JOB SHEET #1

Q. Start at prying notch and pry out lock ring (Figure 11)

FIGURE 11

Source: *FOS Tires and Tracks*, Deere and Company, Moline, Illinois.

R. Using two irons to pry and hold, work around tire to remove lock ring (Figure 12)

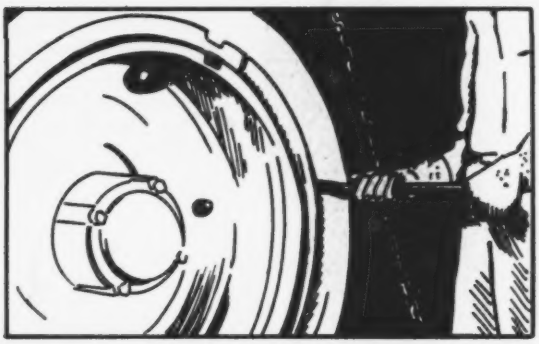
FIGURE 12

Source: *FOS Tires and Tracks*, Deere and Company, Moline, Illinois.

JOB SHEET #1

S. Pry bead-seat band out over gutter section (Figure 13)

FIGURE 13



Source: *FOS Tires and Tracks,* Deere and Company, Moline, Illinois.

T. Remove bead-seat band and side flange from rim base

(CAUTION: Remove the bead-seat band slowly to prevent it from dropping off and crushing your toes. Support the band on your thigh and roll it slowly to the ground. This will protect your back and toes.)

U. Place small jack between vehicle frame and tire

V. Extend jack

(NOTE: By extending jack, pressure is exerted to force the tire bead off the rim taper.)

W. Continue working around tire until bead is loose at all points

(NOTE: Before working tire off the rim, be sure that valve will clear the gutter section.)

X. Work tire off rim

1. Force tire forward as far as possible at bottom
2. Remove jack stand and lower jack enough so that weight of tire rests on ground

   (NOTE: This step will provide clearance at the top to permit you to force the tire out at the top by pushing or prying.)
3. Force tire out at the top

4. While holding upper part of tire out as far as possible, have helper raise the jack so that tire weight rests on top of rim

   (NOTE: By alternating at top and bottom in this way, the tire can be "walked" off the rim. A hoist or crane aids in this operation.)

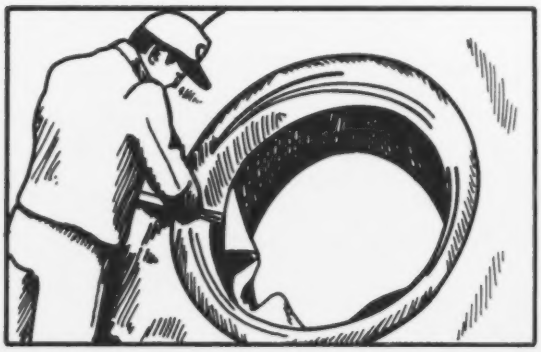
Y. Completely remove tire from wheel

   (NOTE: Leave the tire in a vertical position, leaning against the vehicle.)

Z. Remove flap from tire, using a tool with rounded end to pry out and away from beads (Figure 14)

   (NOTE: On some types of vehicles, you may have to use a tire spreader or a small auto jack to spread the beads and assist in removing the flap.)

FIGURE 14



Source: *FOS Tires and Tracks,* Deere and Company, Moline, Illinois.

AA. Remove tube in the same manner

   (CAUTION: Be careful not to pull on valve stem or to damage tube.)

   (NOTE: To facilitate mounting procedure outlined in Job Sheet #2, leave vehicle jacked up with tire demounted.)

TIRES
UNIT II

JOB SHEET #2 — MOUNT A TUBE-TYPE TIRE

I. Equipment and materials

A. Sand blaster or wire brush

B. Paintbrush

C. Zinc chromate, red lead, or aluminum paint

D. Air compressor

E. Shop towels

F. Safety glasses

G. Approved tire-mounting lubricant

H. Remote-control inflation line with clip-on chuck

I. Tire tools and irons

J. Heavy-duty jack

K. Bead spreader or auto jack

L. Tire pressure gauge

M. Appropriate service manual

II. Procedure

(CAUTION: Failure to follow proper procedures when mounting a tire on a wheel or rim can produce an explosion that may result in serious injury or death. Do not attempt to mount a tire unless you have the proper equipment and expertise to perform the job.)

A. Clean rust from rim base and bead seats

(NOTE: Use a wire brush or a sandblaster if available.)

B. Check all parts of the rim for cracks

(CAUTION: Replace any broken or damaged parts.)

C. Paint all bare metal surfaces with zinc chromate, red lead, or aluminum paint; allow paint to dry thoroughly

JOB SHEET #2

D. Clean all dirt and foreign matter from inside casing

(CAUTION: Be sure to wear safety glasses if using compressed air.)

E. Inspect casing thoroughly inside and out

F. Install tube in casing, working from the bottom completely around tire

G. Add a little air to tube as it is worked into casing (Figure 15)

(NOTE: The added air helps to hold the tube in place and eliminates the possibility of wrinkles.)

FIGURE 15

Source: *FOS Tires and Tracks,* Deere and Company, Moline, Illinois.

H. Insert flap in casing, making sure that it is properly centered and smooth -

I. Rotate tire as flap is worked in, keeping portion being inserted at bottom of tire (Figure 16)

(NOTE: In some cases it may be necessary to spread the beads, using a spreader or auto jack.)

FIGURE 16

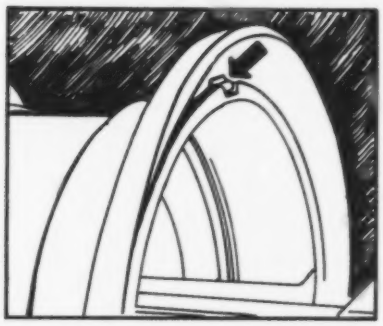
Source: *FOS Tires and Tracks,* Deere and Company, Moline, Illinois.

JOB SHEET #2

J. Lubricate beads with approved rubber lubricant

K. Install rear flange on rim base, and align driving lug with slot in rim (Figure 17)

FIGURE 17



Source: *FOS Tires and Tracks,* Deere and Company, Moline, Illinois.

L. Roll tire into position

M. Make sure that valve stem is aligned with valve slot

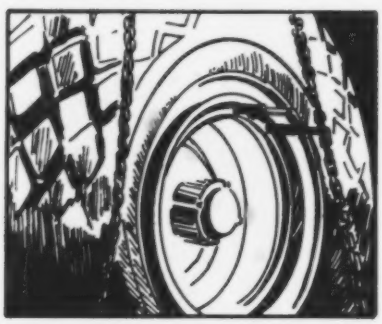
N. Lower jack enough so that top of tire can be hooked over top of rim

O. Raise jack so that tire is clear of ground

P. Walk tire on in the same manner used to demount tire (Job Sheet #1)

Q. Hook two rack tools into rim gutter approximately 4 inches from either side of valve slot (Figure 18)

FIGURE 18



Source: *FOS Tires and Tracks,* Deere and Company, Moline, Illinois.

JOB SHEET #2

R. Place bead-seat band in outside flange, aligning drive lug on flange with slot in bead-seat band

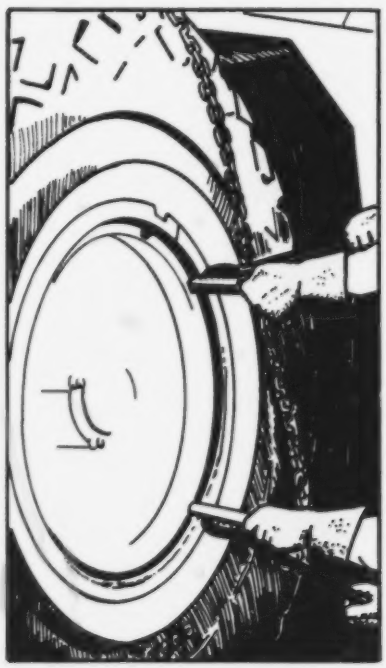
S. Install bead-seat band and side flange in rim base by hooking them over the two side tools and sliding on the rim

(NOTE: Be sure that the driving lug on the bead-seat band is aligned with the valve slot in the rim base.)

T. Engage two bar tools in proper notches of rack tools; pry bead-seat band into position

U. Holding pressure against band with one tool, slide other rack and tool around rim, stopping about every foot to pry the bead-seat band into place (Figure 19)

FIGURE 19



Source: *FOS Tires and Tracks,* Deere and Company, Moline, Illinois.

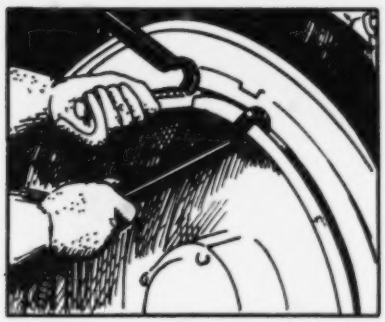
V. Follow up with second rack and tool to hold pressure against band and to keep the clearance gained

W. Circle the rim once in this manner

JOB SHEET #2

X. Hook one bar tool into gutter for additional prying (Figure 20)

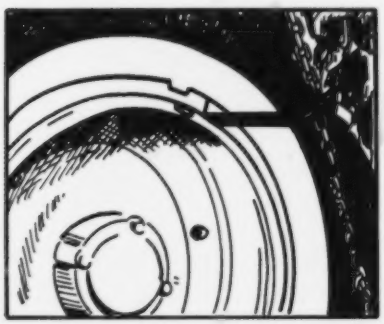
FIGURE 20



Source: *FOS Tires and Tracks,* Deere and Company, Moline, Illinois.

Y. Use two bar tools without the racks, and continue to work around the rim until the bead seat has been forced inside the gutter edge 1 to 1 1/8 inches (Figure 21)

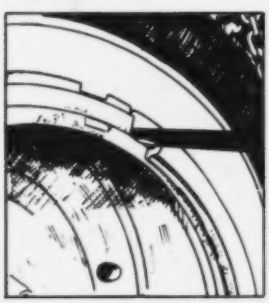
FIGURE 21



Source: *FOS Tires and Tracks,* Deere and Company, Moline, Illinois.

Z. Hold band in this position, and drive the tapered end of bar tool between bead seat and rim base, directly under break in bead-seat band (Figure 22)

FIGURE 22



Source: *FOS Tires and Tracks,* Deere and Company, Moline, Illinois.

JOB SHEET #2

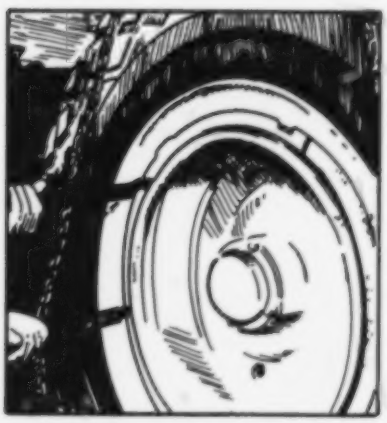
AA. Hook one end of lock ring into gutter (Figure 23)

FIGURE 23

Source: *FOS Tires and Tracks,* Deere and Company, Moline, Illinois.

BB. Use tapered ends of two bar tools to pry or snap lock ring into place (Figure 24)

FIGURE 24



Source: *FOS Tires and Tracks,* Deere and Company, Moline, Illinois.

CC. When lock ring is in place, remove bar tool wedge from between ends of lock ring

DD. Pry bead-seat band out over edge of lock ring

(NOTE: Be sure that no binding occurs when this is done.)

(CAUTION: Never start to inflate a tapered bead tire unless the bead-seat band has been pried out over the lock ring, and for safety, use an inflation cage.)

JOB SHEET #2

EE. Check to make sure that driving lugs on both flanges are engaged

FF. Inflate tire to approximately 75 pounds per square inch (psi) to ensure proper seating of the bead

(CAUTION: When seating tire beads on rims or wheels, never exceed maximum inflation pressures specified by tire manufacturers for mounting tires. Inflation beyond this maximum pressure may break the bead, or even the rim, with dangerous explosive force.)

GG. Deflate tire completely to remove buckles and uneven stresses from tube and flap

HH. Inflate tire to proper operating pressure

(CAUTION: Use a clip-on chuck and extension hose. Stand well to one side when inflating tire.)

(NOTE: Double inflation is necessary to prevent premature tube failure.)

II. Lower machine to the ground; remove jack and wheel blocks

JJ. Clean work area; clean and put away all tools and equipment

TIRES
UNIT II

JOB SHEET #3 — DEMOUNT A TUBELESS TIRE

I. Equipment and materials

A. Hydraulic tire remover

B. Tire tools and irons

C. Heavy-duty jack

D. Wheel blocks

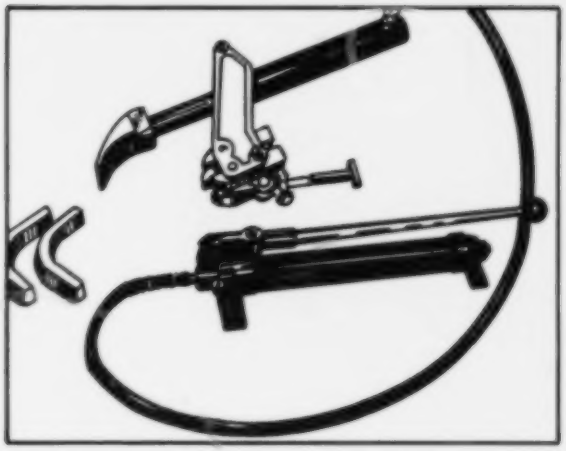
E. Axle stand

II. Procedure

(NOTE: To demount large tubeless tires it is generally necessary to use a hydraulic tire remover. See Figure 25.)

(CAUTION: Bead breakers and rams apply pressure to bead flanges. Keep your fingers clear. Slant bead breaker about 10 degrees to keep it firmly in place. If it slips off, it can be thrown with enough force to kill. Always stand to one side when you apply hydraulic pressure.)

FIGURE 25



Source: *FOS Tires and Tracks*, Deere and Company, Moline, Illinois.

A. Block all wheels securely, except the one being changed

B. Place jack under machine; jack up vehicle until axle stand can be placed under axle

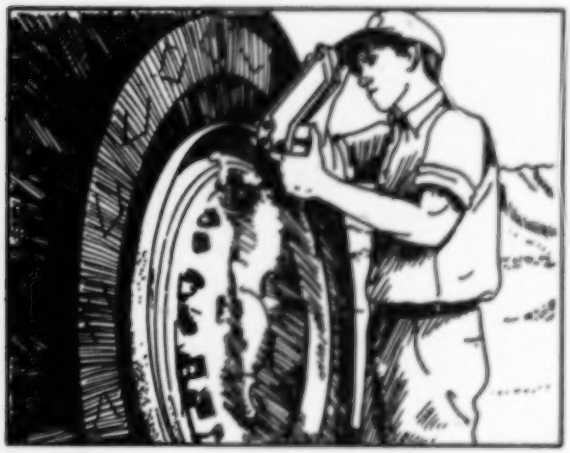
JOB SHEET #3

C. Let jack down just enough so that weight of machine is on jack stand and jack, and tire is clear of ground

D. Remove valve core, and exhaust ALL air pressure from tire

E. Securely tighten adjusting screws at bottom of tire remover jaws (Figure 26)

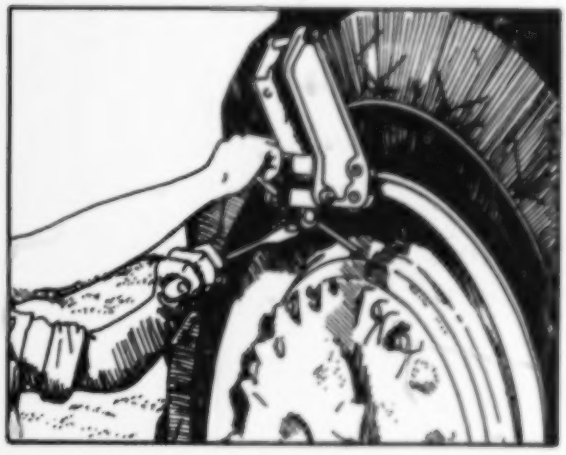
FIGURE 26



Source: *FOS Tires and Tracks*, Deere and Company, Moline, Illinois.

F. Set hand screw against lock ring and adjust until jaw assembly is at right angle to plane of flange (Figure 27)

FIGURE 27



Source: *FOS Tires and Tracks*, Deere and Company, Moline, Illinois.

JOB SHEET #3

G. Insert spade and ram assembly between open sides of frame

(NOTE: Be sure that spade tip is down and that ram is in retracted position.)

H. Place spade tip between tire bead and rim flange

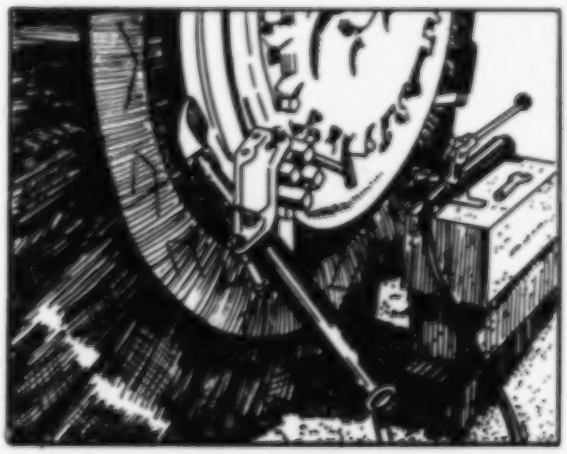
I. Lift ram until trunnion engages frame shoulder support; then move stop screw into the support ram (Figure 28)

FIGURE 28

Source: *FOS Tires and Tracks*, Deere and Company, Moline, Illinois.

J. Use pump to apply pressure to ram and spade until spade moves tire bead toward center of rim assembly far enough to permit placing a bead wedge between bead and flange on each side of tool (Figure 29)

FIGURE 29



Source: *FOS Tires and Tracks*, Deere and Company, Moline, Illinois.

JOB SHEET #3

K. Release pump pressure

L. Remove spade and ram assembly from frame

M. Loosen clamping jaw screws and remove flange

N. Turn wheel approximately 60 degrees and repeat entire procedure (Figure 30)

FIGURE 30

Source: *FOS Tires and Tracks*, Deere and Company, Moline, Illinois.

O. Continue turning and repeating these procedures until tire is free of rim

(NOTE: To facilitate mounting procedure outlined in Job Sheet #4, leave vehicle jacked up with tire demounted.)

TIRES
UNIT II

JOB SHEET #4 — MOUNT A TUBELESS TIRE

I. Equipment and materials

- A. Wire brush or sandblaster
- B. Paintbrush
- C. Zinc chromate, red lead, or aluminum paint
- D. Air compressor
- E. Shop towels
- F. Safety glasses
- G. Approved tire-mounting lubricant
- H. Remote-control inflation line with clip-on chuck
- I. Tubeless tire-changing tools
  1. Off-the-road tire-changing tools
  2. Bead-breaking tools
- J. Heavy-duty jack
- K. Axle stand
- L. Tire pressure gauge
- M. Appropriate service manual

II. Procedure

- A. Clean off rim base and bead seats

  (NOTE: Use wire brush or a sandblaster if available.)

- B. Check all parts of rim for damage or corrosion

  (CAUTION: Replace any broken or damaged parts. Always replace old O-ring with a new one, and be sure to lubricate O-rings with rubber lubricant.)

- C. Paint all bare metal surfaces with zinc chromate, red lead, or aluminum paint

JOB SHEET #4

D. Clean all dirt and foreign matter from inside casing

(CAUTION: Be sure to wear safety glasses if using compressed air to clean inside of casing.)

E. Inspect casing thoroughly inside and out

F. Lubricate O-ring gutter and area behind it for about 2 inches with rubber lubricant

G. Make sure that valve stem is properly installed in rim base

H. Install rear flange in rim base

I. Push flange to the back flange of rim base

(NOTE: Be sure that the drive lug on the flange properly engages slot in the rim base. See Figure 31.)

FIGURE 31

Source: *FOS Tires and Tracks*, Deere and Company, Moline, Illinois.

J. Place tire on rim base, and force back as far as possible against back flange

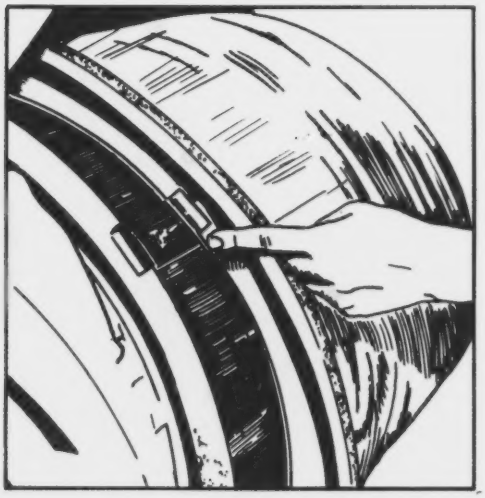
K. Align drive lug with slot in rim base

L. Place outside rim flange on rim base, making sure that drive lug on flange is about 5 inches to the right of drive lug on rim base

JOB SHEET #4

M. Install tapered bead-seat band over rim base, forcing it between flange and rim base (Figure 32)

FIGURE 32



Source: *FOS Tires and Tracks*, Deere and Company, Moline, Illinois.

N. Align drive lug on flange with drive lug slot in tapered bead-seat band

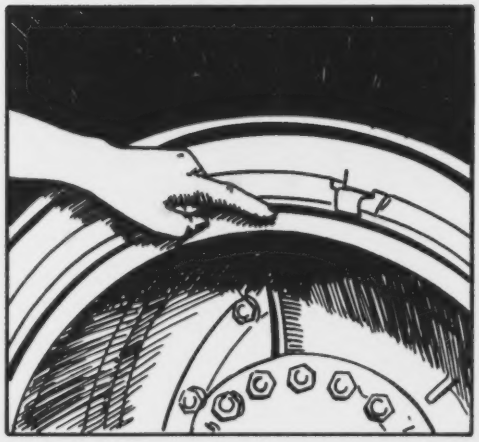
O. Use tire irons to force outside flange assembly, tapered bead-seat band, and outside tire bead in far enough to clear ring gutters; hold in this position

JOB SHEET #4

P. Insert lock ring in outside gutter and tap into place, making sure that drive lug on lock ring fits into slot in rim base gutter (Figure 33)

(NOTE: Be sure that all slots and drive lugs are properly aligned. If it is necessary to move any of the parts, use only a lead or brass hammer.)

FIGURE 33



Source: *FOS Tires and Tracks*, Deere and Company, Moline, Illinois.

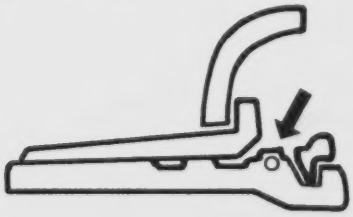
Q. Lubricate O-ring gasket with approved rubber lubricant

R. Place bottom of O-ring over lock ring and into gutter without twisting or rolling

S. Lubricate the bands

T. Spread ring over rim base and lock ring; snap into place at top (Figure 34)

FIGURE 34



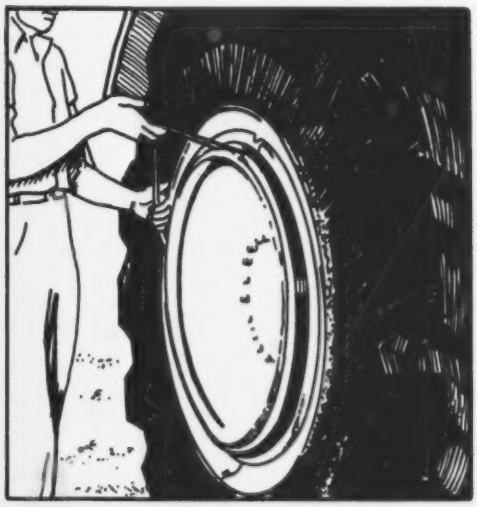
Source: *FOS Tires and Tracks*, Deere and Company, Moline, Illinois.

JOB SHEET #4

U. Lubricate O-ring area again by applying rubber lubricant with a brush

V. Pull tapered bead-seat band and outside flange out over O-ring as tightly as possible against lock ring (Figure 35)

FIGURE 35



Source: *FOS Tires and Tracks*, Deere and Company, Moline, Illinois.

W. Check to be sure that all rim parts are properly assembled

X. Inflate to pressure recommended by tire manufacturer to seat the beads

(CAUTION: Use clip-on chuck and extension hose. Stand well to one side while inflating. Never exceed maximum pressures specified by tire manufacturer for mounting tires. Inflation beyond this maximum pressure may break the bead, or even the rim, with dangerous explosive force. For safety, use an inflation cage if available.)

Y. Deflate tire to recommended cold pressure

Z. Check to be sure there are no air leaks in the assembly

AA. Raise jack enough to remove axle stand

BB. Lower machine to ground; remove jack and wheel blocks

CC. Clean work area; clean and put away all tools and equipment

TIRES
UNIT II

JOB SHEET #5 — REPAIR A TIRE

I. Equipment and materials

A. Small punch or scribe

B. Scraper or buffer

C. Insertion tool

D. Sharp knife

E. Stitching tool

F. Vulcanizing tool

G. Vulcanizing fluid

H. Repair plugs

I. Cold and hot patches

J. Tire pressure gauge

K. Remote-control inflation line with clip-on chuck

L. Appropriate service manual

II. Procedure

(NOTE: For radial ply tires, repairs can be made *only* in the central tread area between the major outside grooves.)

A. Remove tire from rim (Job Sheet #1 or Job Sheet #3)

B. Probe injury to remove nails or other damaging items

C. Clean out casing and make sure that area around injury is completely dry

JOB SHEET #5

D. Use scraper or buffer to clean and slightly roughen damaged area (Figure 36)

(CAUTION: Be careful not to damage the liner or expose any cords.)

FIGURE 36

Source: *FOS Tires and Tracks,* Deere and Company, Moline, Illinois.

E. Lubricate damaged spot by pushing snout of vulcanizing fluid can into damaged spot from both inside and outside of tire (Figure 37)

FIGURE 37

Source: *FOS Tires and Tracks,* Deere and Company, Moline, Illinois.

JOB SHEET #5

F. Cover insertion tool with vulcanizing fluid and push it through the damaged spot with a twisting motion (Figure 38)

FIGURE 38

Source: *FOS Tires and Tracks*, Deere and Company, Moline, Illinois.

G. Continue movement of tool until it can be inserted and withdrawn easily

H. Insert a repair plug (slightly larger than the damaged spot) into the eye of insertion tool

(NOTE: A head-type or headless straight plug may be used. If a headless straight plug is used, it must always be backed up with a patch.)

I. Cover plug and insertion tool with vulcanizing fluid

J. While holding and stretching long end of plug, insert plug into damaged spot from inside of tire (Figure 39)

FIGURE 39

Source: *FOS Tires and Tracks*, Deere and Company, Moline, Illinois.

JOB SHEET #5

K. Remove insertion tool with a twisting motion

L. Cut off plug about 1/16 inch above surface of tire (Figure 40)

(NOTE: Do not pull on plug while cutting it.)

FIGURE 40

Source: *FOS Tires and Tracks*, Deere and Company, Moline, Illinois.

M. Cover entire damaged area with vulcanizing fluid, and allow to dry

N. Remove backing from cold patch

O. Center patch over damaged spot and press down firmly

P. Use stitching tool to stitch patch down firmly, working from center out (Figure 41)

FIGURE 41

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Source: *FOS Tires and Tracks*, Deere and Company, Moline, Illinois.

JOB SHEET #5

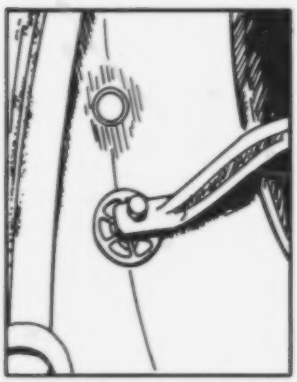
Q. Clean and deburr tire rim

R. Remount tire (Job Sheet #2 or Job Sheet #4)

S. Inflate tire and check for leaks

(NOTE: The same procedures may be used when applying hot patches. Use specified type of patch and fluid, apply heat with hot-patch vulcanizing tool, cure, and allow to cool. See Figure 42.)

FIGURE 42



Source: *FOS Tires and Tracks*, Deere and Company, Moline, Illinois.

T. Clean work area; clean and put away all tools and equipment

TIRES
UNIT II

TEST

NAME _____ SCORE _____

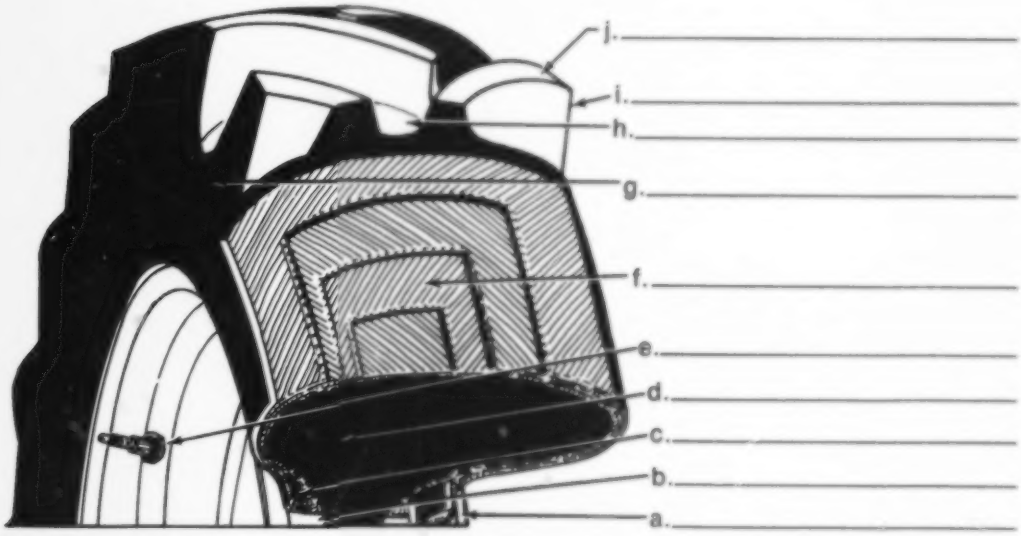
1. Match to their correct definitions terms associated with tires. Write the correct numbers in the blanks.

_____a.	Bundles of wire that form the tire foundation to which all tire plies are tied; anchors tire to rim and prevents changes of fit on rim	1. Flex
_____b.	Salt-like agent used to prevent water from freezing when water is used as ballast inside a tire	2. Calcium chloride
_____c.	Layers of rubber-cushioned cord or fabric insulated from the next layer of the same compound; hold in the inflation pressure that supports load and cushions shock	3. Deflate/deflation
_____d.	To stretch or bend	4. Flotation
_____e.	Strength of tire; identifies a given tire with its recommended load when used for a specific type of service	5. Rim
_____f.	Act, process, or state of floating; ability to stay on the surface of soft ground or snow	6. Ballast
_____g.	Weight added to tire or wheel to produce better traction and drawbar pull	7. Body plies
_____h.	Process of removing air pressure from a tire; state of being deflated	8. Inflate/inflation
_____i.	Outer part of wheel that supports the tire	9. Bead
_____j.	Percentage of slip of the drive wheels	10. Ply rating
_____k.	Process of putting air into a tire; state of being inflated	11. Travel reduction

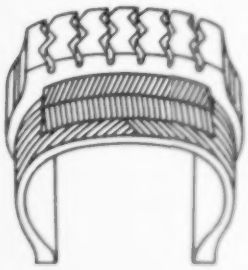
TEST

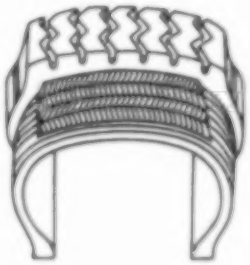
2. Identify the parts of the tire illustrated below. Write the correct names in the blanks.

Tread	**Body plies**	**Bead**
Rim	**Valve stem**	**Tread shoulder**
Air container	**Sidewall**	**Rim flange**
Tread depth		



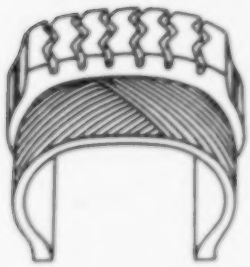
3. Label ply construction of the following tires.





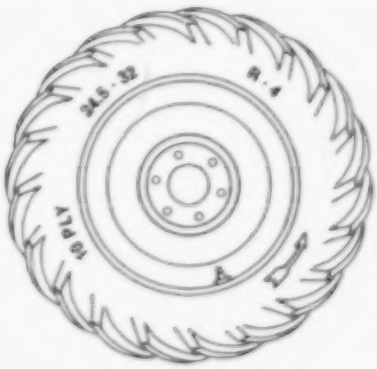
a. _____ b. _____

TEST



c. _____

4. Explain the meaning of the numbers and arrows on the tire sidewall illustrated below.



a. R-4 — _____

_____

b. 32 — _____

_____

c. 24.5 — _____

_____

d. 10 ply — _____

_____

e. Arrow — _____

_____

TEST

5. Describe overinflation, underinflation, and proper inflation.

   a. Overinflation — _____

   _____

   _____

   b. Underinflation — _____

   _____

   _____

   c. Proper inflation — _____

   _____

   _____

6. Name three factors that determine amount of ballast to use on equipment.

   a. _____

   b. _____

   c. _____

7. Discuss travel reduction.

   _____

   _____

   _____

   _____

8. Name materials used for wheel ballast.

   a. _____

   b. _____

   c. _____

TEST

9. List four advantages of dual tires.

a. _____

_____

b. _____

_____

c. _____

_____

d. _____

_____

10. List four causes of tire failure.

a. _____

b. _____

c. _____

d. _____

11. State ten safety rules to observe when demounting, inflating, or mounting tires.

a. _____

_____

b. _____

_____

c. _____

_____

d. _____

_____

TEST

e. _____

_____

f. _____

_____

g. _____

_____

h. _____

_____

i. _____

_____

j. _____

_____

(NOTE: Test question 12 lists the job sheets. They are an important part of this test. If they have not been completed, check with your instructor.)

12. Demonstrate the ability to

    a. Demount a tube-type tire.

    b. Mount a tube-type tire.

    c. Demount a tubeless tire.

    d. Mount a tubeless tire.

    e. Repair a tire.

TIRES
UNIT II

ANSWERS TO TEST

1.

a.	9	d.	1	g.	6	j.	11
b.	2	e.	10	h.	3	k.	8
c.	7	f.	4	i.	5		

2.

a.	Rim flange	f.	Body plies
b.	Rim	g.	Sidewall
c.	Bead	h.	Tread depth
d.	Air container	i.	Tread shoulder
e.	Valve stem	j.	Tread

3.
a. Belted bias
b. Belted radial
c. Bias

4.
a. R-4 — Denotes that tire is an industrial, intermediate tread
b. 32 — Indicates nominal diameter of rim in inches
c. 24.5 — Indicates section width of tire in inches when mounted on its recommended rim
d. 10 ply — Identifies recommended load when tire is used in a specific type of service; tells strength of tire
e. Arrow — Indicates forward rotation of drive-wheel tires

5. Description should include the following
a. Overinflation — Tire is too rigid and can be damaged by impacts; prevents full contact of tire with ground; causes excessive wear at center of tread
b. Underinflation — Too much tread contacts ground; tires flex too much and heat up; causes excessive wear on sides of tread
c. Proper inflation — Provides full tread contact with ground; ensures proper traction and flotation; prevents too much or too little flexing

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ANSWERS TO TEST

6. Answer should include any three of the following

   a. Type of equipment and job it is performing

   b. Soil surface

   c. Equipment power output

   d. Travel speed

   e. Tires

7. Discussion should include the following

   a. Under normal conditions, slip should be about 10 to 15 percent; zero slip is not good

   b. If less than 10 percent slip, remove weight; if more than 15 percent slip, add more weight

8. a. Liquid

   b. Cast iron

   c. Dry powder

9. Answer should include any four of the following

   a. Provide more ground contact, thus reduce slippage, increase ground speed, improve work rates, and possibly lessen fuel consumption

   b. Provide improved machine stability

   c. Provide smooth ride, thus help prevent driver fatigue

   d. Provide more flotation, thus help keep machine on top of ground

   e. Have better potential for all-season use

   f. Permit use of equipment under adverse weather and soil conditions

   g. Permit a machine with one tire requiring service to be moved to a convenient place for repairs

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ANSWERS TO TEST

10. Answer should include any four of the following

    a. Fabric break

    b. Rubber checks

    c. Wear from spinning wheels

    d. Bruises

    e. Valve damage

    f. Tread and sidewall cuts

    g. Grease and oil damage

    h. Obstructions (frame or fender rubbing tire)

11. Answer should include any ten of the following

    a. Follow proper procedures and manufacturer's recommendations

    b. Block wheels on other side of vehicle before placing jack in position

    c. Always use a wood block under jack when working on the ground

    d. Never attempt to unseat beads of an inflated tire; remove valve core and exhaust ALL air pressure before removing a tire

    e. Deflate tires on multipiece wheels before removing the wheel

    f. Do not attempt to inflate or repair tires without proper tools

    g. Never stand in front of, or over tire when inflating

    h. Always use a clip-on chuck and extension hose when inflating tires

    i. Use an inflation cage whenever possible

    j. Keep hands and feet away from pinch points when using bead breakers and other tire tools

    k. Never attempt to lift or move heavy tires and wheels without help; use a cable or chain sling if necessary

    l. Handle tire and wheel or rim assemblies carefully

ANSWERS TO TEST

m. When seating tire beads on rim, never exceed maximum inflation pressure

n. Never start to inflate a tapered-bead tire unless the bead-seat band has been pried out over the lock ring

o. Always match rim parts properly

p. Always keep a firm grip on tire irons and tools

q. Carefully clean all dirt from lock ring gutter to allow gutter to fit securely in its proper position

r. Never attempt to rework, weld, heat, or braze wheel parts; instead, always replace them with new parts

s. Never transport a fully inflated tire; inflate tire only after tire and rim assembly have been mounted

12. Performance skills evaluated to the satisfaction of the instructor

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SUSPENSION SYSTEMS
UNIT III

UNIT OBJECTIVE

After completing this unit, the student should be able to repair and adjust various parts of suspension systems. The student will show this knowledge by completing job sheets and unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match to their correct definitions terms associated with suspension systems.
2. List types of suspension systems used on wheeled vehicles.
3. List types of suspension systems used on crawler tractors.
4. List principal parts of suspension systems.
5. Select from a list types of springs used on suspension systems.
6. Select from a list types of shock absorbers used on suspension systems.
7. Label basic parts of a coil spring suspension system used on a wheeled vehicle.
8. Label basic parts of a suspension system used on a crawler tractor.
9. Identify various types of spring shackles.
10. Discuss operation of crawler suspension system.
11. State reasons for track oscillation.
12. Discuss types of oscillating connections used on side frames to support center section of crawler.
13. Demonstrate the ability to
    a. Remove torsion bar, links, and equalizer bar; perform inspection and reassemble.
    b. Adjust suspension system at stop blocks.
    c. Remove and replace a pivot shaft.

SUSPENSION SYSTEMS
UNIT III

SUGGESTED ACTIVITIES

I. Suggested activities

A. Gather equipment and materials for job sheet demonstrations.

B. Obtain transparencies.

(NOTE: Transparencies are available from AGC and CIMC.)

C. Provide students with objective sheet.

D. Discuss unit and specific objectives.

E. Provide students with information and job sheets.

F. Discuss information sheet.

G. Demonstrate and discuss procedures outlined in job sheets.

H. Give test.

I. Complete appropriate section of competency profiles.

(NOTE: Competency profiles are available from AGC and CIMC.)

II. Instructional materials

A. Objective sheet

B. Suggested activities

C. Information sheet

D. Transparency masters

1. TM #1 — Semielliptical Leaf Spring
2. TM #2 — Coil Spring
3. TM #3 — Torsion Bar Spring
4. TM #4 — Volute Spring
5. TM #5 — Air Spring
6. TM #6 — Auxiliary Spring

1799

7. TM #7 — Single-Acting Cam-Operated Shock Absorber
8. TM #8 — Double-Acting Cam-Operated Shock Absorber
9. TM #9 — Shock Absorbers
10. TM #10 — Free Track Action

E. Job sheets

1. Job Sheet #1 — Remove Torsion Bar, Links, and Equalizer Bar; Perform Inspection and Reassemble
2. Job Sheet #2 — Adjust Suspension System at Stop Blocks
3. Job Sheet #3 — Remove and Replace a Pivot Shaft

F. Test

G. Answers to test

III. Unit references

A. Armstrong, Ivan D. *Auto Mechanics,* Vol. I. Stillwater, Oklahoma: State Department of Vocational and Technical Education/Curriculum and Instructional Materials Center, 1976.

B. Departments of the Army and the Air Force. *Principles of Automotive Vehicles,* (TM 9-8000-to 36A-1-76). Washington, D.C.: U.S. Government Printing Office, 1956.

C. *850 Crawler Service Manual 9-72942,* rev. Racine, Wisconsin: J I Case, a Tenneco Company, 1975.

SUSPENSION SYSTEMS
UNIT III

INFORMATION SHEET

I. Terms and definitions

A. Bogie — Suspension unit consisting of tandem axles joined by a single cross support (trunnion axle) that acts as a vertical pivot for entire unit

B. Coil spring — Special spring steel rod wound into a spiral coil; one end attaches to frame and the other to axle or control arm

C. Equalizer rod — Straight steel rod with a yoke assembly on each end; connects to both torsion bars to transmit a twisting force from one torsion bar to other

D. Oscillate — To move up and down independently

E. Shackle — Swinging support that permits a leaf spring to vary in length as it is deflected

F. Shock absorber — Device placed at a vehicle wheel to regulate spring rebound and compression

G. Stabilizer bar — Transverse-mounted spring steel bar that minimizes body leaning or tipping while cornering

H. Suspension system — Supporting device that allows vehicle to travel over rough terrain with a minimum amount of up and down movement to vehicle body

I. Torsion bar — Long spring steel bar that flexes by twisting about its axis; allows vehicle body to move up and down

J. Volute spring — Helical coil spring made from flat steel tapered both in width and thickness

II. Types of suspension systems used on wheeled vehicles

A. Independent axle

B. Bogie axle

C. Independent wheel

D. Single arm

E. Torsion bar

INFORMATION SHEET

F. Double arm

G. Double articulated arm

III. Types of suspension systems used on crawler tractors

A. Torsion bar

B. Horizontal

C. Vertical

D. Articulated bogie

E. Single arm

F. Double arm

G. Double articulated arm

H. Christie

(NOTE: Christie systems are used on many foreign crawler tractors. Full-sized wheels are used instead of the small bogie and track-supporting wheels.)

IV. Principal parts of suspension systems

A. Springs

B. Torsion bars

C. Shock absorbers

D. Bogies

E. Wheels

F. Tracks

V. Types of springs used on suspension systems (Transparencies #1-#6)

A. Semielliptical leaf spring

B. Coil spring

C. Torsion bar spring

D. Volute spring

INFORMATION SHEET

E. Air spring

F. Auxiliary spring (secondary spring)

VI. Types of shock absorbers used on suspension systems (Transparencies #7-#9)

A. Single-acting cam-operated

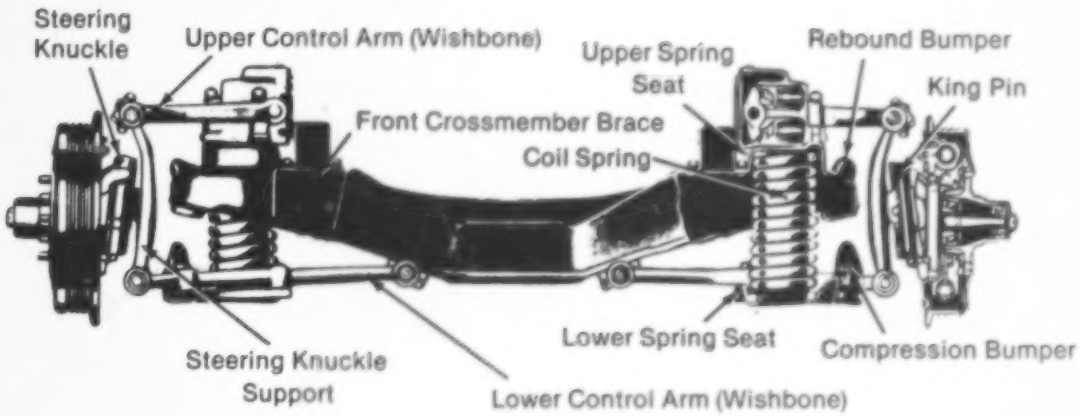
B. Double-acting cam-operated

C. Double-acting vane-operated

D. Direct-acting

VII. Basic parts of a coil spring suspension system used on a wheeled vehicle (Figure 1)

FIGURE 1

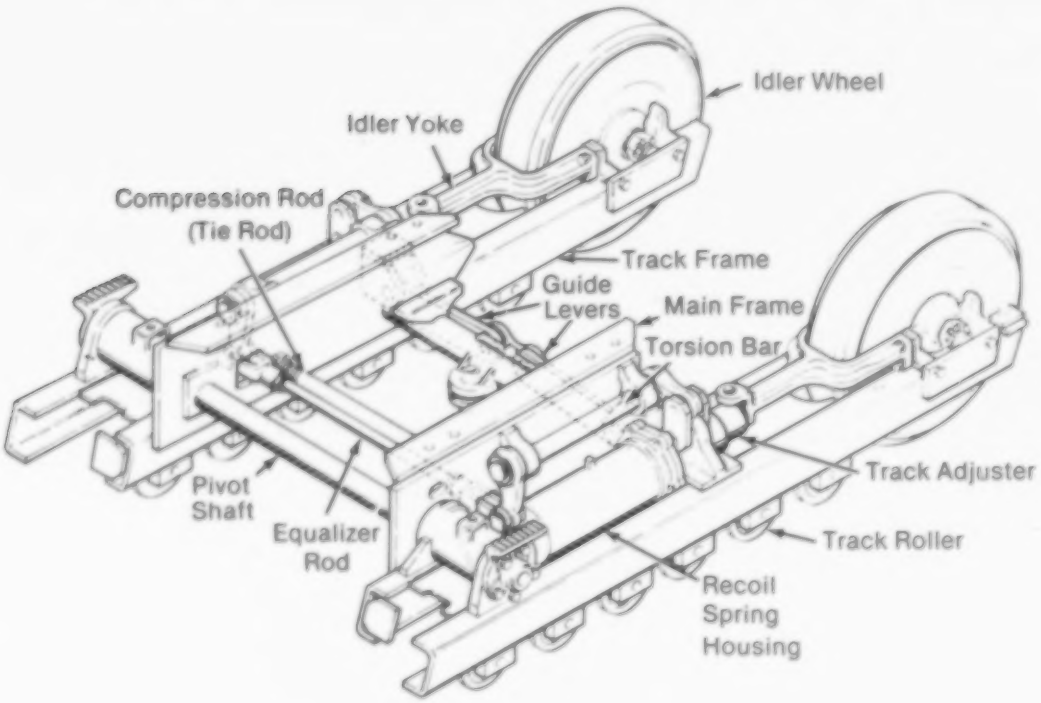


INFORMATION SHEET

VIII. Basic parts of a suspension system used on a crawler tractor (Figure 2)

(NOTE: These parts are from a J I Case 850 crawler suspension system. Parts may vary on other manufacturers' products.)

FIGURE 2



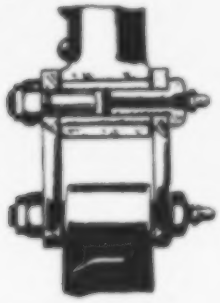
Used with permission of J I Case, a Tenneco Company.

INFORMATION SHEET

IX. Various types of spring shackles (Figures 3-9)

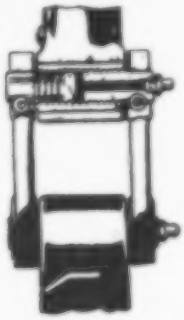
A. Bolt

FIGURE 3



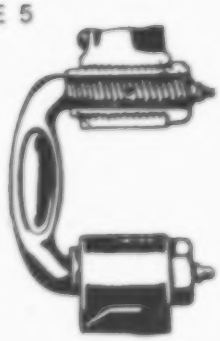
B. Straight-threaded

FIGURE 4



C. U-type

FIGURE 5



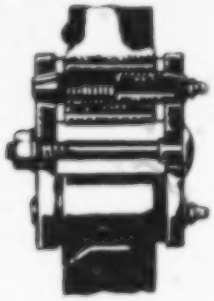
INFORMATION SHEET

D. Pin and bolt

FIGURE 6

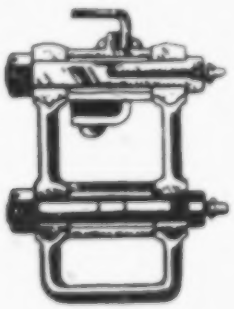
E. Center bolt

FIGURE 7



F. Single-piece link

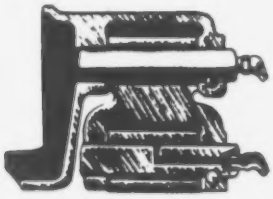
FIGURE 8



INFORMATION SHEET

G. Y-shackle

FIGURE 9

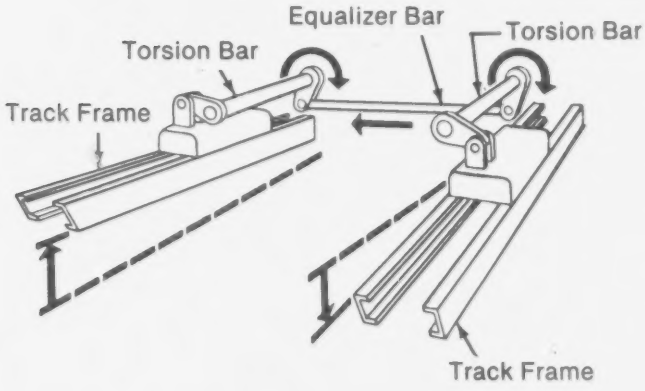


X. Operation of crawler suspension system (Transparency #10)

A. When a track encounters an obstacle, the track rises to pass over the obstruction without raising vehicle or twisting torsion bar

B. Force is transmitted by equalizer rod to opposite torsion bar, which twists to force front of opposite track downward (Figure 10)

FIGURE 10



Used with permission of J I Case, a Tenneco Company.

C. By permitting free track action, this system and the independent main frame provide a smooth, even ride by eliminating damaging shocks and strains

XI. Reasons for track oscillation

A. Provides for more accurate dozer work

B. Allows for better stability

C. Provides better traction on uneven surfaces

D. Improves riding comfort

XII. Types of oscillating connections used on side frames to support center section of crawler

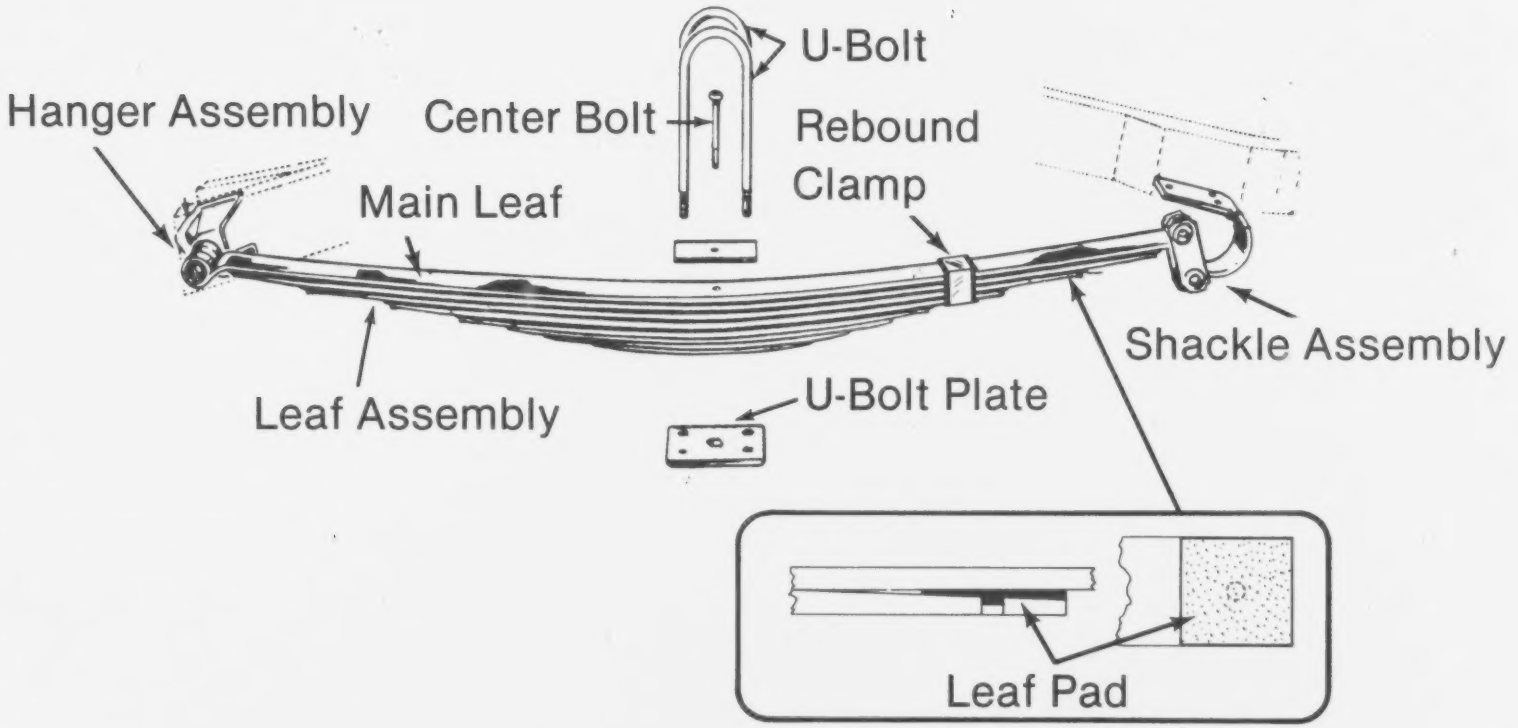
A. Spring-type — Usually a heavy leaf-type spring; the ends rest on the track frames and the center supports center frame

(NOTE: These springs tend to compress and allow the center frame on a dozer to move down when the blade is lifted and to move up when it is dropped, thus interfering with accuracy of control.)

B. Stabilizer bar — Rigid bar connected to track frame and center frame; allows oscillation without spring action

1876

Semielliptical Leaf Spring



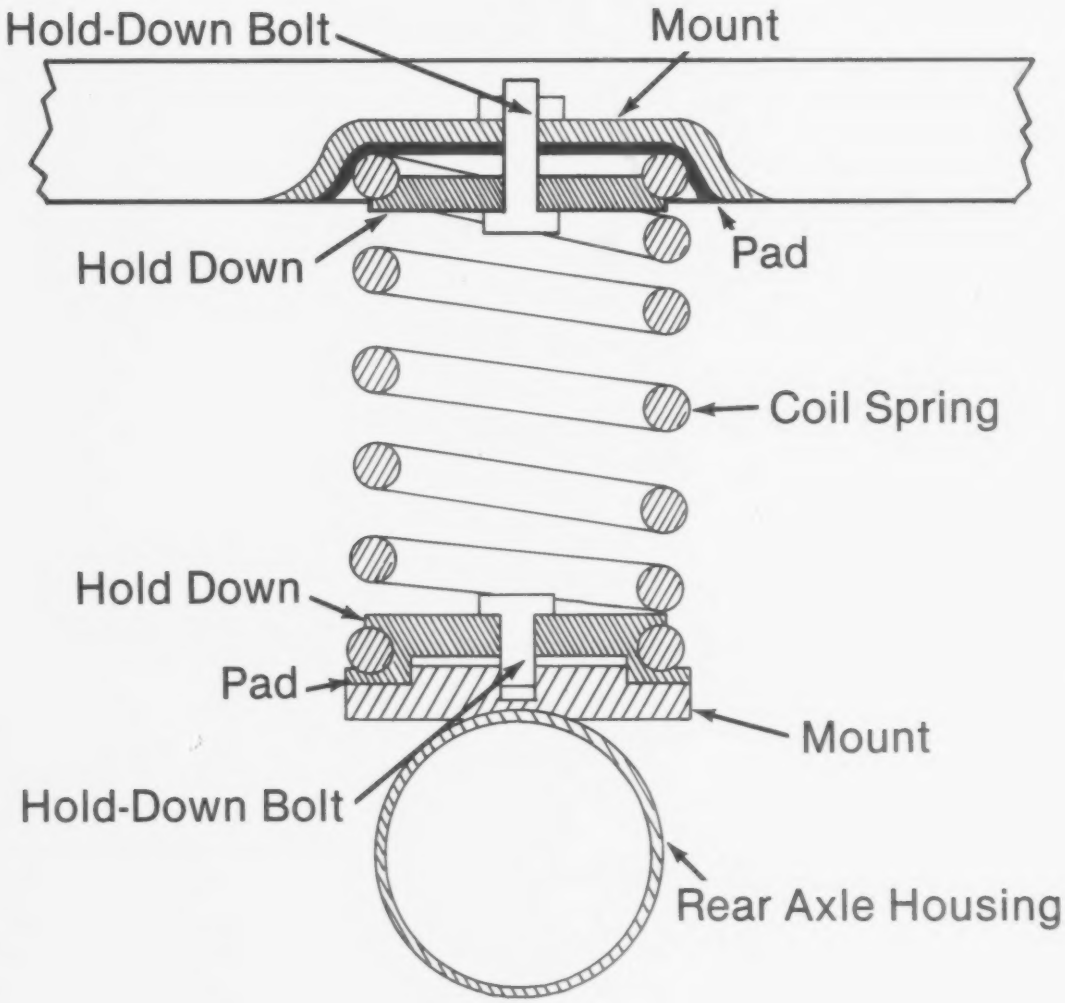
1807

1808

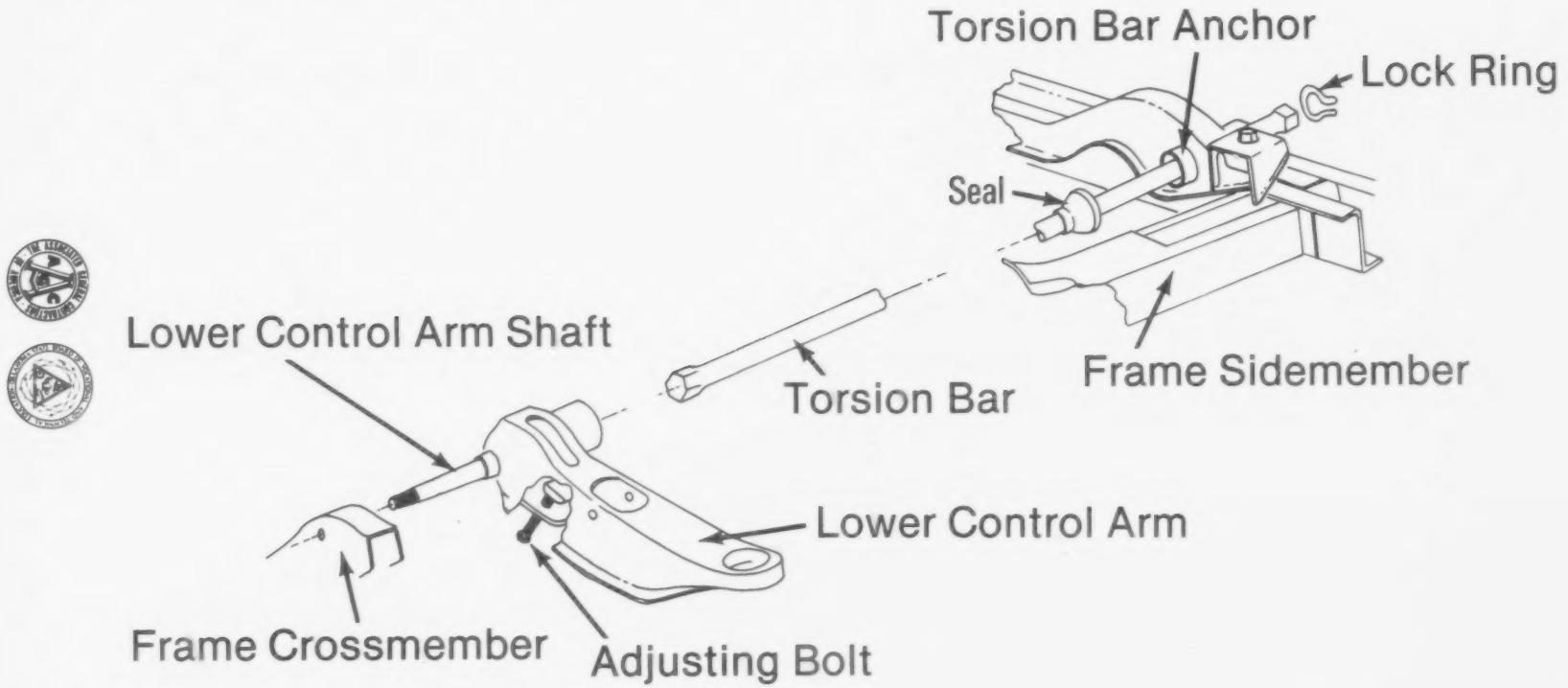
TM #1

HEM - 119-F

Coil Spring


Hold-Down Bolt
Mount
Hold Down
Pad
Coil Spring
Hold Down
Pad
Mount
Hold-Down Bolt
Rear Axle Housing

Torsion Bar Spring



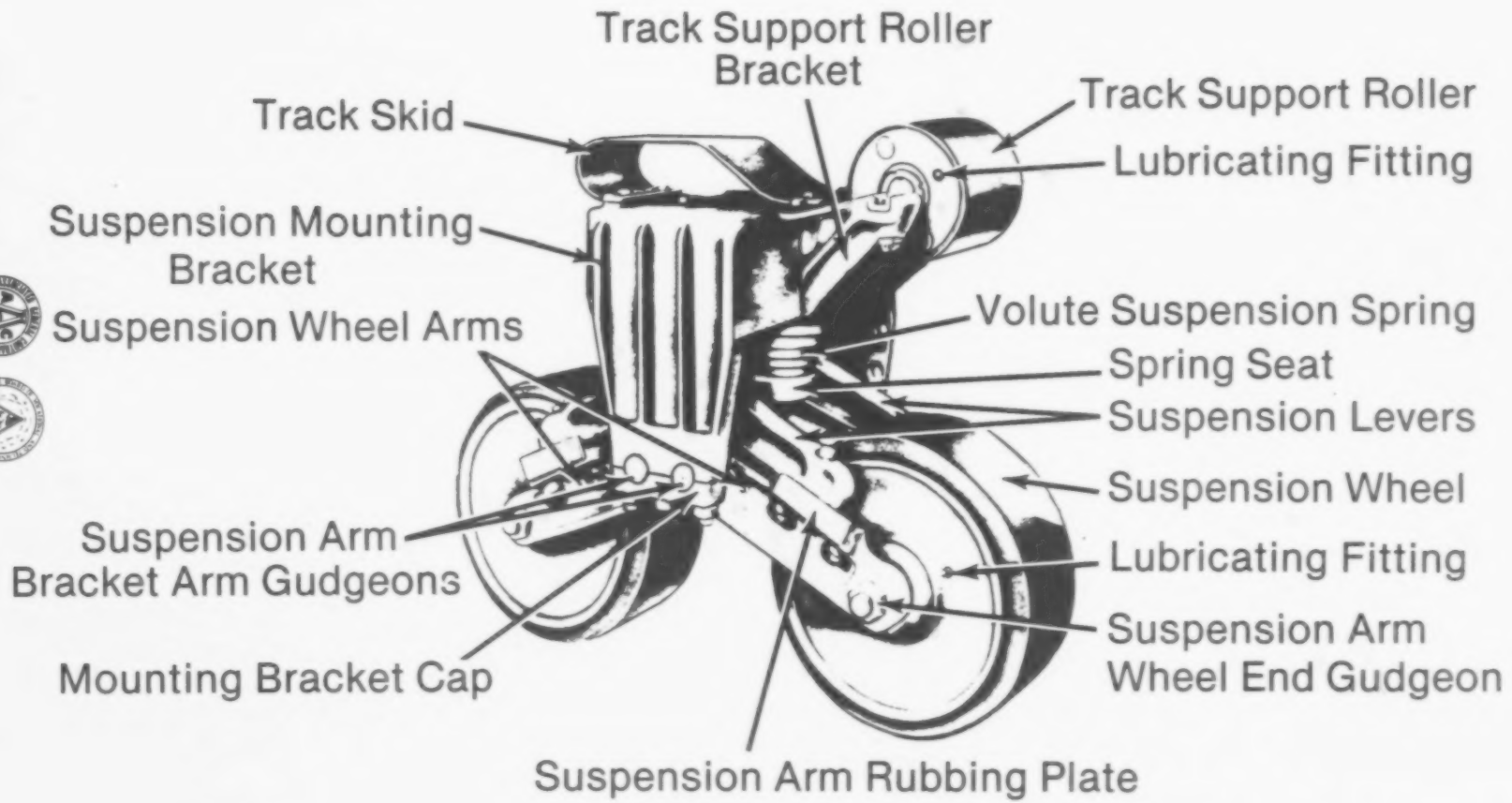
1810

1811

TM #3

HEM - 123-F

Volute Spring



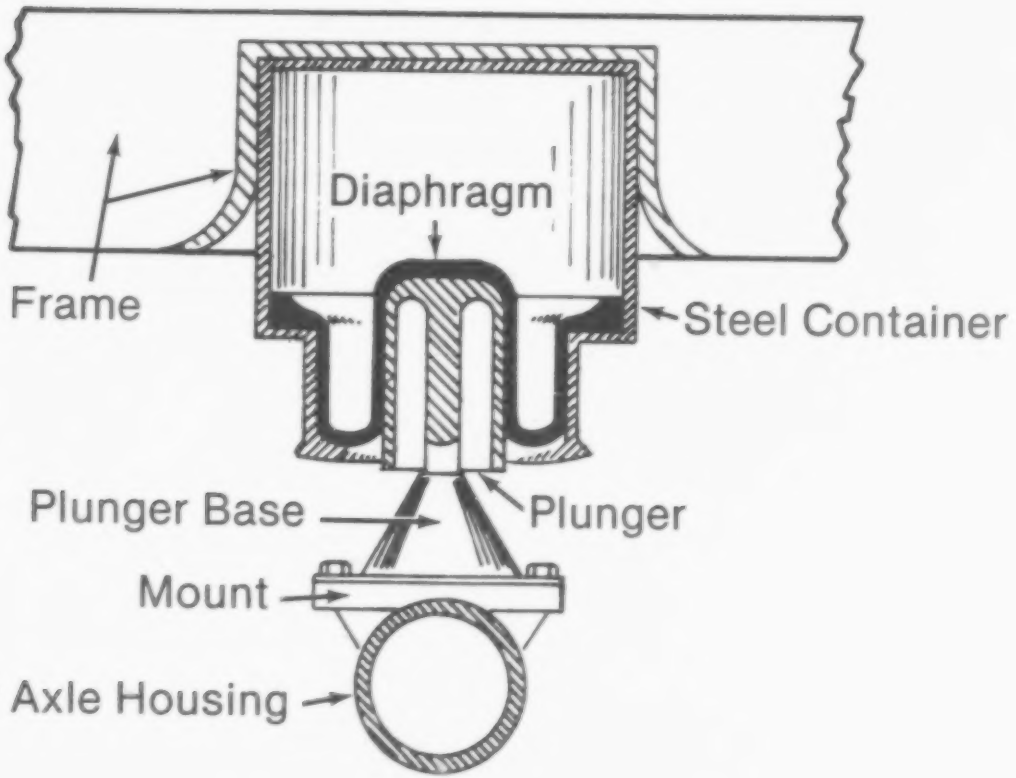
1812

1813

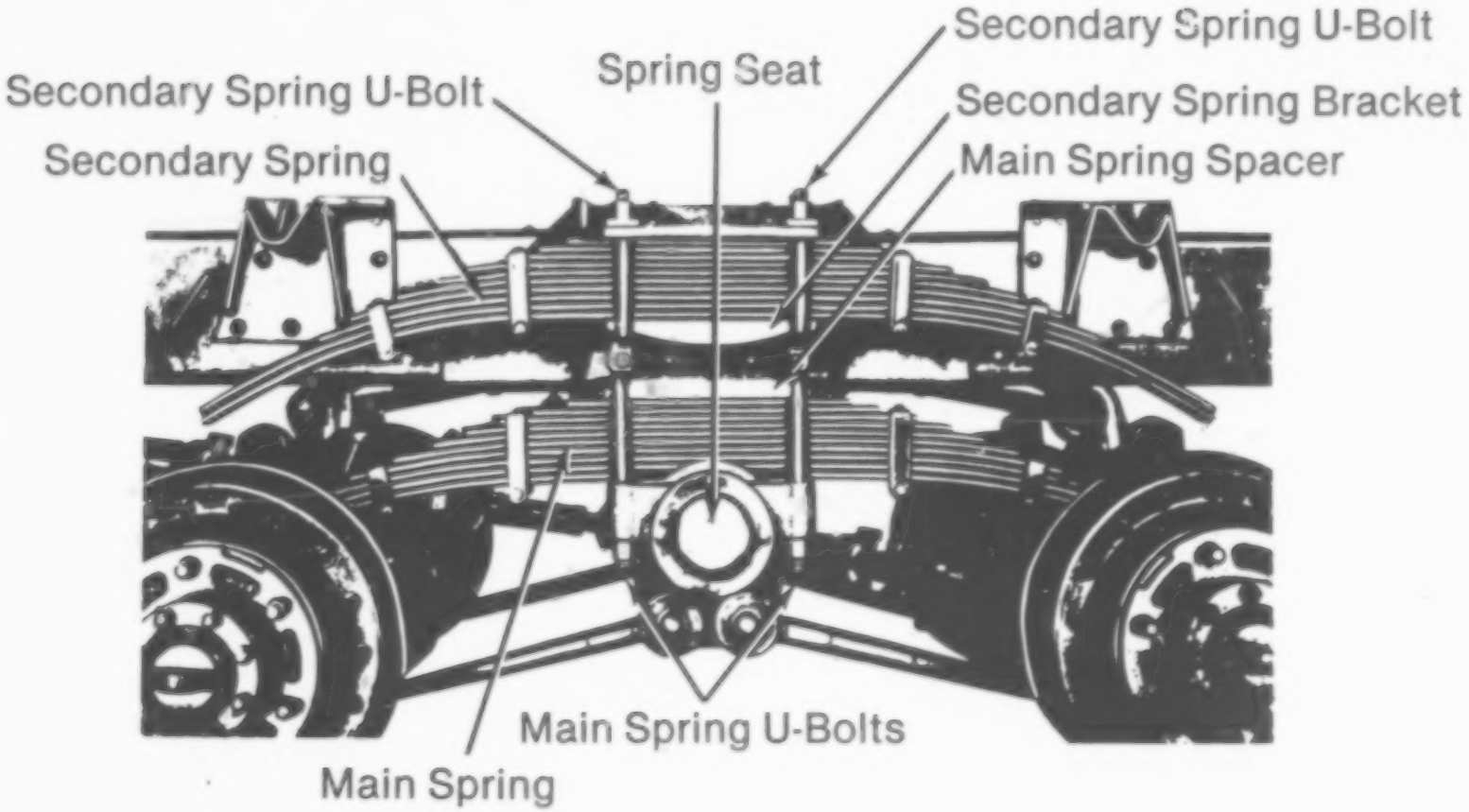
TM #4

HEM - 125-F

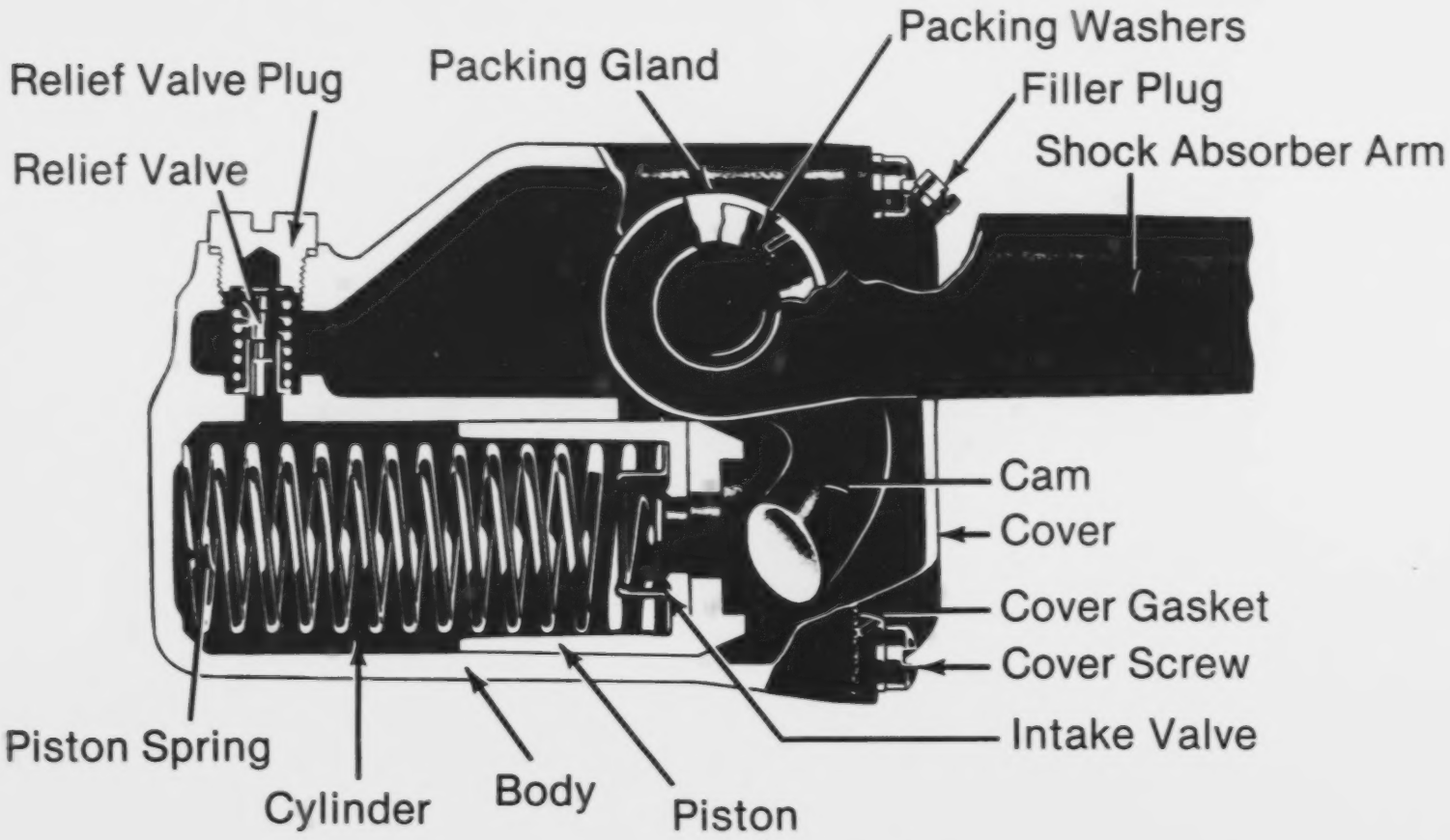
Air Spring


Diaphragm
Frame
Steel Container
Plunger Base
Plunger
Mount
Rear Axle Housing

Auxiliary Spring



Single-Acting Cam-Operated Shock Absorber



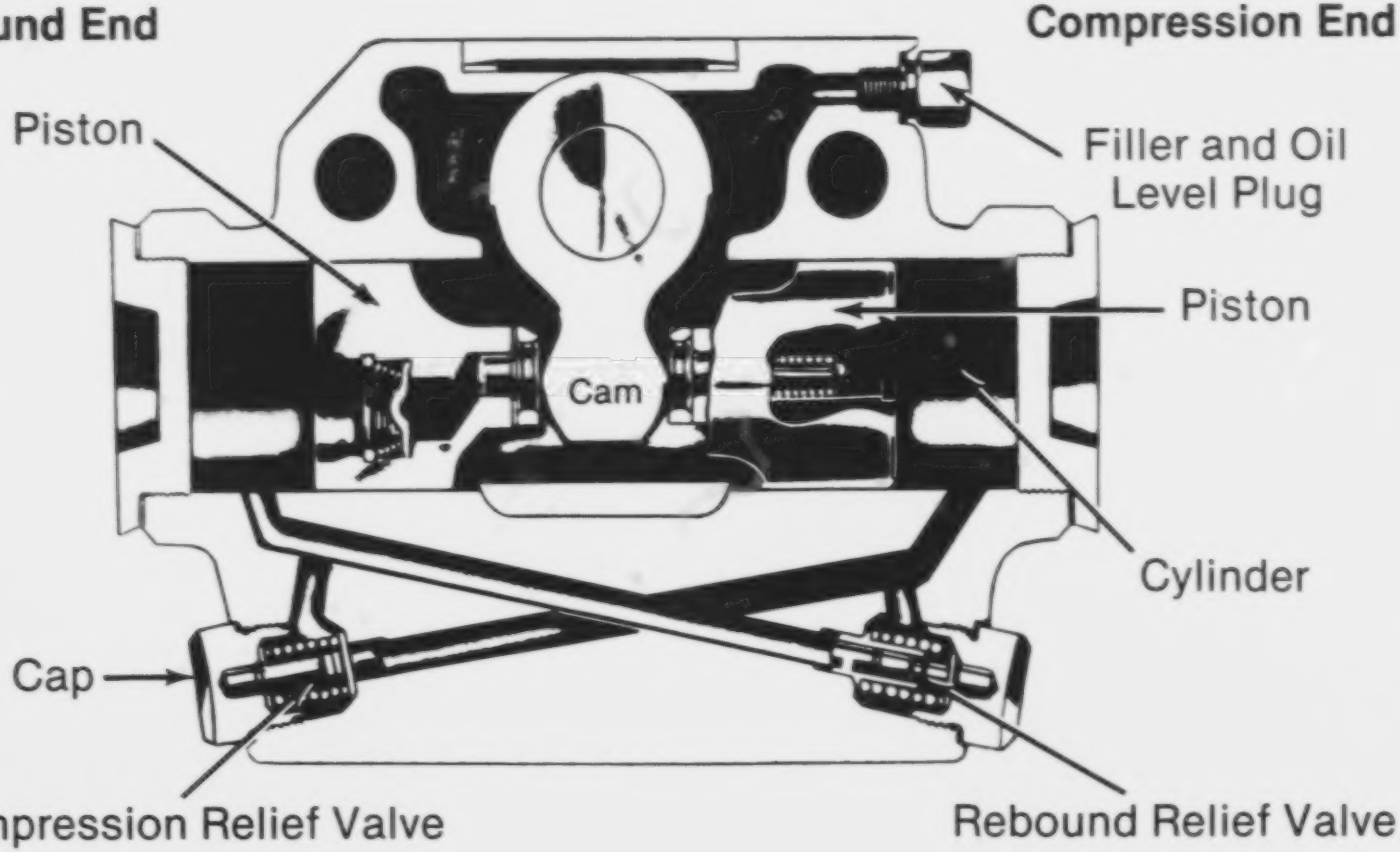
1818

1819

TM #7

HEM - 131-F

Double-Acting Cam-Operated Shock Absorber



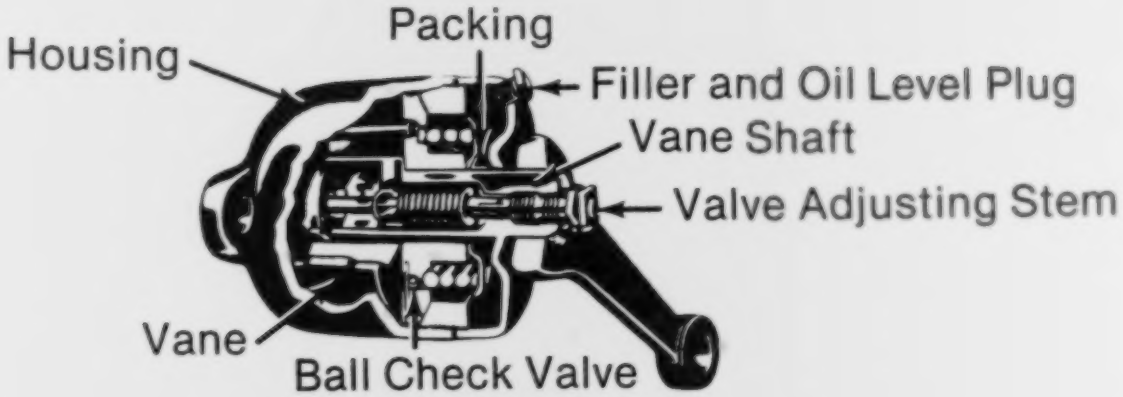
TM #8

1820

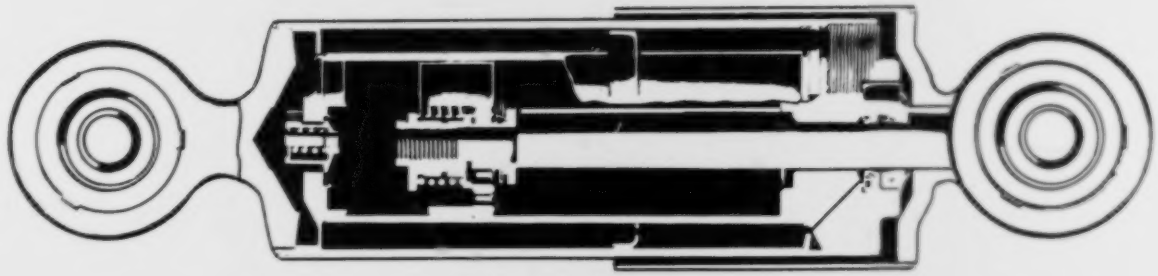
1821

HEM - 133-F

Shock Absorbers



Double-Acting Vane-Operated



Direct-Acting

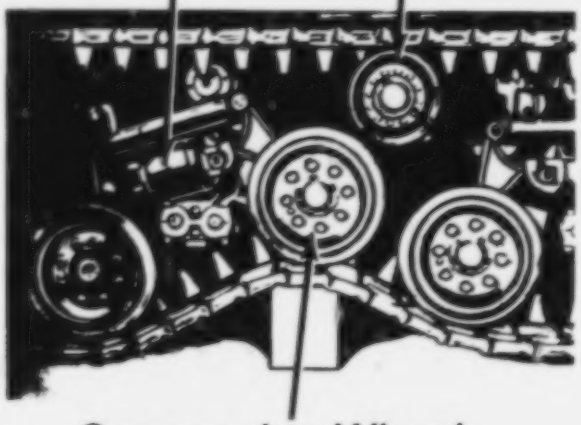
1822

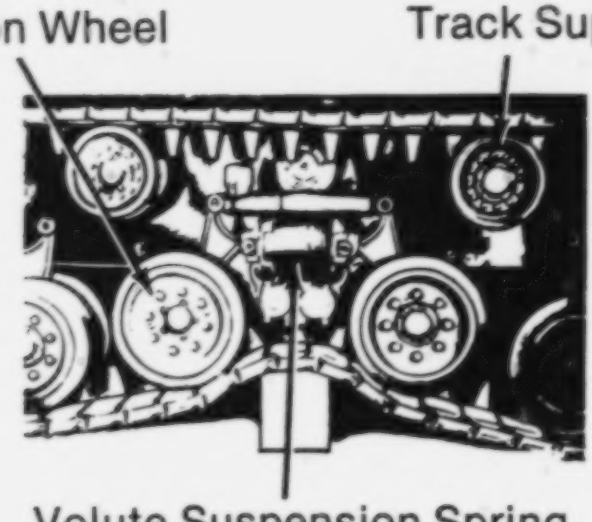
1823

TM #9

HEM - 135-F

Free Track Action





SUSPENSION SYSTEMS
UNIT III

JOB SHEET #1 — REMOVE TORSION BAR, LINKS, AND EQUALIZER BAR; PERFORM INSPECTION AND REASSEMBLE

I. Equipment and materials

A. Crawler

B. Basic hand-tool set

C. Pry bar or steel wedge

D. Scriber

E. Wooden blocks

F. Jacks or hoist

G. Cleaning solvent

H. Shop towels

I. Grease or lubricant recommended by manufacturer

J. Anti-seize compound recommended by manufacturer

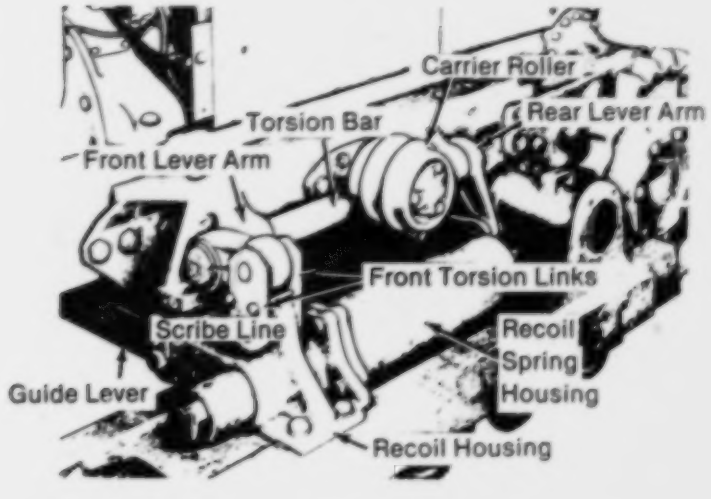
K. Supply of spacers and shims

L. Appropriate service manual

II. Procedure for disassembly and inspection (Figure 11)

(NOTE: This procedure is written specifically for a J I Case 850 crawler. Procedure may vary slightly with other manufacturers' products.)

FIGURE 11



Adapted with permission of J I Case, a Tenneco Company.

JOB SHEET #1

A. Raise front of crawler to relieve tension from torsion bar and linkage

B. Place blocks under front of crawler to support weight

C. Remove two tie bolts, washers, and nuts that connect links

D. Remove front torsion links (See Figure 11)

(NOTE: Links can be separated with a pry bar or steel wedge.)

E. Remove link washers and pins

F. Remove torsion bar snap ring and any shims from front of torsion bar

G. Scribe front lever arm (See Figure 11)

(NOTE: Scribing assures alignment of the splines in the same position when reassembling.)

H. Remove front lever arm (See Figure 11)

I. Remove snap ring, shims, or spacers from rear of torsion bar

J. Scribe torsion bar and rear lever

K. Remove torsion bar by driving from rear

L. Continue driving until bar is free from front and rear torsion bar brackets

(NOTE: If the bar is too difficult to move through the brackets, replace front lever arm and use it as a lever to pull out the bar.)

M. Remove snap rings and yoke pin to remove rear lever arm

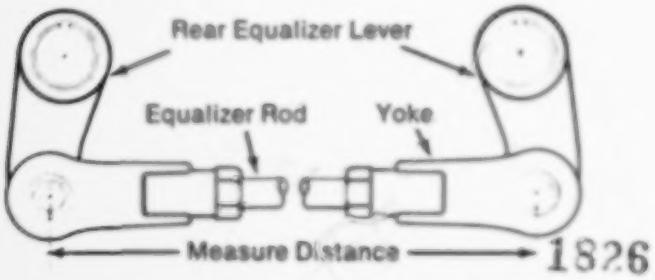
N. Remove bushings from torsion bar brackets

O. Use the same procedure to disassemble other side of suspension system

P. Remove equalizer bar assembly without disturbing jam nuts

(NOTE: If any parts on the assembly are to be replaced, measure distance between center lines of the yoke holes. This will aid in reassembly. See Figure 12.)

FIGURE 12



Adapted with permission of J I Case, a Tenneco Company.

JOB SHEET #1

Q. Thoroughly clean all parts

R. Inspect splines and wearing surfaces of torsion bars and lever arms; replace if necessary

S. Replace bushings in torsion bar brackets and rear lever arms

T. Inspect equalizer yoke pin and bushings; replace if necessary

(NOTE: Early models do not have these bushings.)

III. Procedure for reassembly

A. Cover torsion bars with thin coat of grease

B. Install bars in brackets

(NOTE: As torsion bar starts to come through rear bracket, install rear lever with scribe marks lined up just far enough on bar to hold it in place.)

C. Assemble equalizer rod

1. Coat threads on rod with anti-seize compound

2. Install jam nuts on each end of rod

3. Install yoke on each end and turn each the same number of turns until correct measurement is reached

D. Move rear lever arms up and out of way

E. Insert assembled equalizer rod through main frame

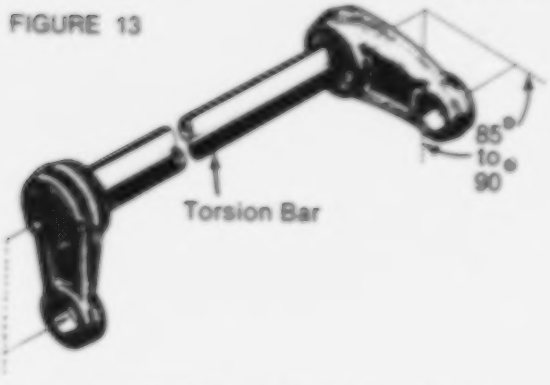
F. Connect rod to lever arms with yoke pins and snap rings

G. Replace on rear of torsion bars any shims or spacers previously removed; install snap ring

H. Install front lever arms

(NOTE: Be sure that scribe marks on lever arm and torsion bar are aligned. If new parts are used, be sure that there is an 85-degree to 90-degree angle between center lines of the two lever arms. See Figure 13.)

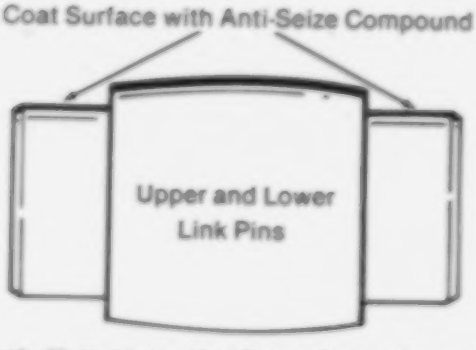
FIGURE 13



Used with permission of J I Case, a Tenneco Company.

I. Coat link pins with anti-seize compound (Figure 14)

FIGURE 14



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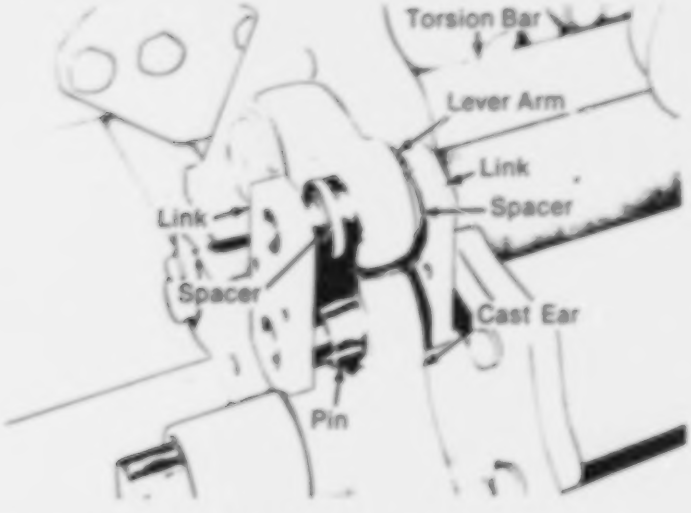
JOB SHEET #1

J. With lower link pin, install front lever arm links, washers, and pin with a spacer on each side of lever arm to cast ear on recoil housing (Figure 15)

FIGURE 15



Adapted with permission of J I Case, a Tenneco Company

K. Install tie bolts, washers, and nuts on torsion links

L. Install front torsion bar snap rings

M. Remove blocks from under front of crawler

N. Lower crawler until it rests on the torsion bar system

O. Remove jacks or hoist

P. Clean work area; clean and put away all tools and equipment

SUSPENSION SYSTEMS
UNIT III

JOB SHEET #2 — ADJUST SUSPENSION SYSTEM AT STOP BLOCKS

I. Equipment and materials

A. Crawler

B. Basic hand-tool set

C. Rule or tape

D. Pipe wrench

E. Shop towels

F. Appropriate service manual

II. Procedure

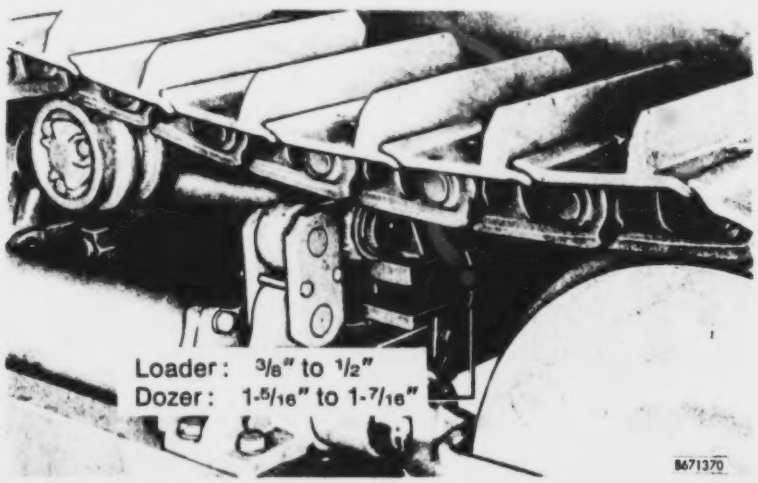
(NOTE: This procedure is written specifically for a JI Case 850 crawler. Procedure may vary slightly with other manufacturers' products.)

A. Raise blade 5 to 10 inches off ground

(NOTE: A specified gap must exist between stop blocks on the main frame and track frame. On loaders, the distance should be 3/8 to 1/2 inch; on drawbars and dozers, the distance should be 1 5/16 to 1 7/15 inches.)

B. Measure clearance between stop blocks (Figure 16)

FIGURE 16



Adapted with permission of J I Case, a Tenneco Company.

1990

JOB SHEET #2

C. Adjust clearance by turning equalizer rod

1. Loosen jam nut on each end of equalizer rod
2. Turn equalizer rod with a pipe wrench as required to raise or lower track frame
3. Remeasure clearance
4. Tighten jam nuts

D. Clean work area; clean and put away all tools and equipment

SUSPENSION SYSTEMS
UNIT III

JOB SHEET #3 — REMOVE AND REPLACE A PIVOT SHAFT

I. Equipment and materials

A. Vehicle

B. Basic hand-tool set

C. 2 jacks

D. Heavy hammer

E. Cleaning solvent

F. Repair kit for pivot shaft brackets

G. New bushings and seals

H. Supply of shims

I. Grease or lubricant recommended by manufacturer

J. Loctite compound

K. Wire (to be used for lockwire)

L. Shop towels

M. Appropriate service manual

II. Procedure for removal

(NOTE: This procedure is written specifically for a J I Case 850 Crawler. Procedure may vary slightly with other manufacturers' products.)

A. Remove belly pan under pivot shaft

B. Remove rear attachment and mounting arms clamped to pivot shaft

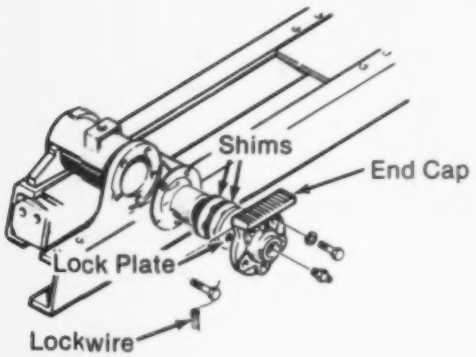
C. Place jacks under main frame and engine frame

D. Raise jacks as required to take weight off pivot shaft

JOB SHEET #3

E. Remove pivot shaft end caps (Figure 17)

FIGURE 17

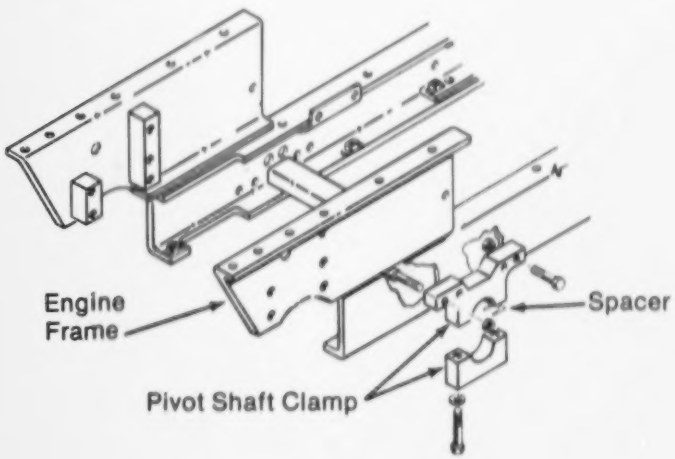


Used with permission of J I Case, a Tenneco Company.

F. Remove shims and lock plates

G. Remove bolts from pivot shaft clamps; then remove bottom halves of pivot shaft clamps (Figure 18)

FIGURE 18



Used with permission of J I Case, a Tenneco Company.

H. Drive out pivot shaft

(CAUTION: End of pivot shaft should be protected to prevent damage.)

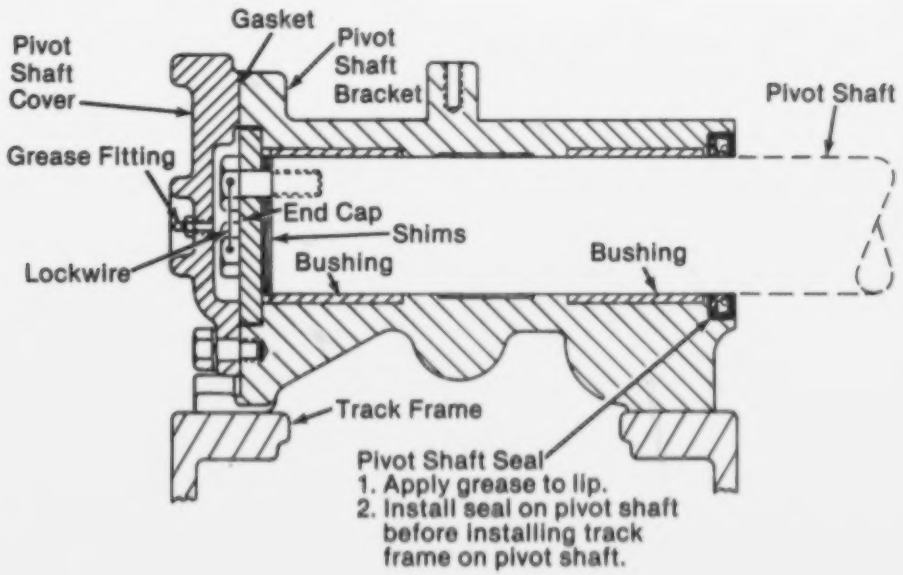
JOB SHEET #3

I. Inspect all parts, seals, and bushings in main frame and track frame

J. Replace pivot shaft

III. Procedure for replacement (Figure 19)

FIGURE 19



Adapted with permission of J I Case, a Tenneco Company.

A. Use repair kit to replace seals and bushings

1. Apply grease to seal lips and inside of bushings

2. Replace bushings and seals

B. Apply Loctite to clamp bolt threads

C. Attach shaft clamp on engine frame with nuts and bolts

D. Drive pivot shaft into place

E. Align pivot shaft so that both ends are an equal distance from both sides of main frame

JOB SHEET #3

F. Install pivot shaft clamps

   1. Place spacer between clamp halves on one side
   2. Tighten bolts on that side first
   3. Place spacer between clamp halves on other side; tighten bolts

G. Reinstall shims and lock plates on ends of pivot shaft

H. Reinstall end caps so that grease relief on back side of end cap is in line with grease relief in pivot shaft bracket

I. Check track frame alignment; adjust as necessary

J. Secure lock plate bolts with lockwire

K. Apply lithium soap-based grease recommended by manufacturer to ends of pivot shaft

L. Reinstall rear attachment

M. Lower and remove jacks

N. Replace belly pan

O. Clean work area; clean and put away all tools and equipment

SUSPENSION SYSTEMS
UNIT III

TEST

NAME _____ SCORE _____

1. Match to their correct definitions terms associated with suspension systems. Write the correct numbers in the blanks.

_____a.	Special spring steel rod wound into a spiral coil; one end attaches to frame and the other to axle or control arm	1. Shackle
_____b.	Helical coil spring made from flat steel tapered both in width and thickness	2. Suspension system
_____c.	Swinging support that permits a leaf spring to vary in length as it is deflected	3. Bogie
_____d.	To move up and down independently	4. Stabilizer bar
_____e.	Supporting device that allows vehicle to travel over rough terrain with a minimum amount of up and down movement to vehicle body	5. Coil spring
_____f.	Straight steel rod with a yoke assembly on each end; connects to both torsion bars to transmit a twisting force from one torsion bar to other	6. Shock absorber
_____g.	Device placed at a vehicle wheel to regulate spring rebound and compression	7. Torsion bar
_____h.	Transverse-mounted spring steel bar that minimizes body leaning or tipping while cornering	8. Volute spring
_____i.	Long spring steel bar that flexes by twisting about its axis; allows vehicle body to move up and down	9. Equalizer rod
_____j.	Suspension unit consisting of tandem axles joined by a single cross support (trunnion axle) that acts as a vertical pivot for entire unit	10. Oscillate

TEST

2. List five types of suspension systems used on wheeled vehicles.

   a. _____

   b. _____

   c. _____

   d. _____

   e. _____

3. List five types of suspension systems used on crawler tractors.

   a. _____

   b. _____

   c. _____

   d. _____

   e. _____

4. List four principal parts of suspension systems.

   a. _____

   b. _____

   c. _____

   d. _____

5. Select from the following list types of springs used on suspension systems. Write an "X" in the blank before each correct answer.

   _____a. Main spring

   _____b. Air spring

   _____c. Recoil spring

   _____d. Equalizer rod

   _____e. Semielliptical leaf spring

   _____f. Volute spring

TEST

6. Select from the following list types of shock absorbers used on suspension systems. Write an "X" in the blank before each correct answer.

_____a. Direct-acting vane-operated

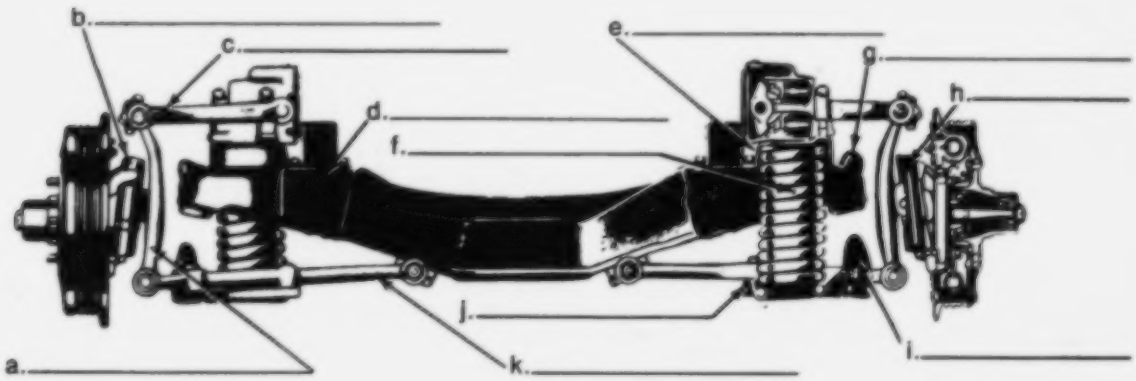
_____b. Double-acting cam-operated

_____c. Single-acting cam-operated

_____d. Double-acting vane-operated

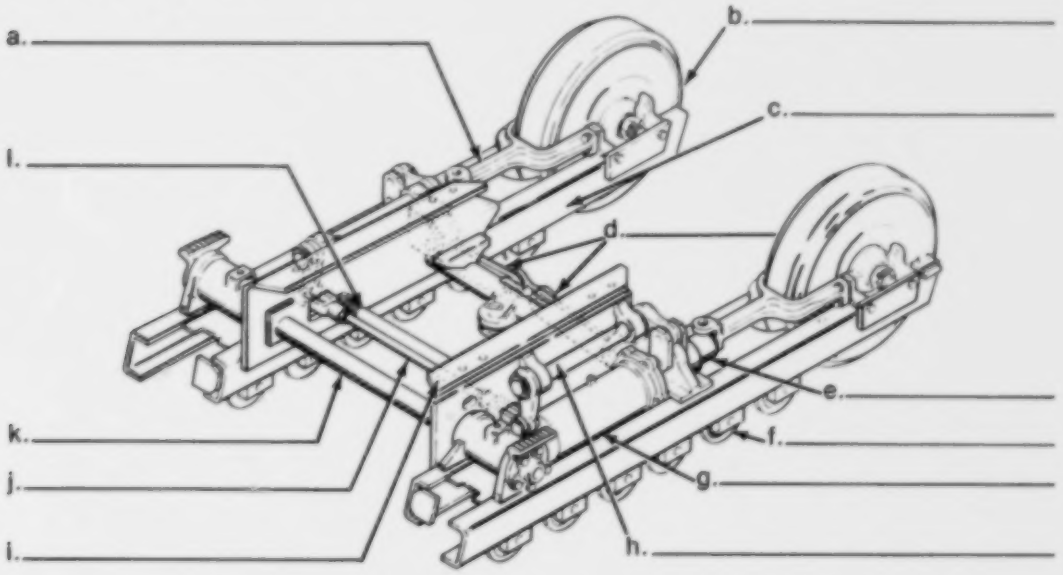
_____e. Double-acting piston

7. Label basic parts of the coil spring suspension system illustrated below. Write the correct names in the blanks.



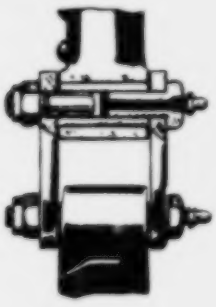
TEST

8. Label basic parts of the crawler suspension system illustrated below. Write the correct names in the blanks.



9. Identify types of spring shackles illustrated below. Write the correct names in the blanks.

Bolt
U-type
Straight-threaded

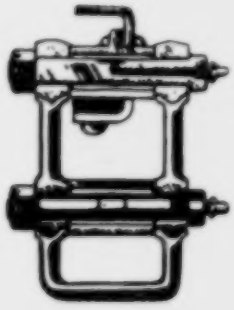


a. _____

Single-piece link
Pin and bolt

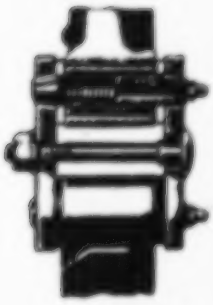
b. _____

Center bolt
Y-shackle



c. _____

TEST



d. _____ e. _____ f. _____

g. _____

10. Discuss operation of crawler suspension system.

a. _____

_____

_____

b. _____

_____

_____

c. _____

_____

_____

TEST

11. State three reasons for track oscillation.

    a. _____

    b. _____

    c. _____

12. Discuss types of oscillating connections used on side frames to support center section of crawler.

    a. _____

    _____

    b. _____

    _____

(NOTE: Test question 13 lists the job sheets. They are an important part of this test. If they have not been completed, check with your instructor.)

13. Demonstrate the ability to

    a. Remove torsion bar, links, and equalizer bar; perform inspection and reassemble.

    b. Adjust suspension system at stop blocks.

    c. Remove and replace a pivot shaft.

SUSPENSION SYSTEMS
UNIT III

ANSWERS TO TEST

1.

a.	5	f.	9
b.	8	g.	6
c.	1	h.	4
d.	10	i.	7
e.	2	j.	3

2. Answer should include any five of the following

a.	Independent axle	e.	Torsion bar
b.	Bogie axle	f.	Double arm
c.	Independent wheel	g.	Double articulated arm
d.	Single arm		

3. Answer should include any five of the following

a.	Torsion bar	e.	Single arm
b.	Horizontal	f.	Double arm
c.	Vertical	g.	Double articulated arm
d.	Articulated bogie	h.	Christie

4. Answer should include any four of the following

a.	Springs	d.	Bogies
b.	Torsion bars	e.	Wheels
c.	Shock absorbers	f.	Tracks

5. b, e, f

ANSWERS TO TEST

6. b, c, d

7.
a.	Steering knuckle support	g.	Rebound bumper
b.	Steering knuckle	h.	King pin
c.	Upper control arm (wishbone)	i.	Compression bumper
d.	Front crossmember brace	j.	Lower spring seat
e.	Upper spring seat	k.	Lower control arm (wishbone)
f.	Coil Spring		

8.
a.	Idler yoke	g.	Recoil spring housing
b.	Idler wheel	h.	Torsion bar
c.	Track frame	i.	Main frame
d.	Guide levers	j.	Equalizer rod
e.	Track adjuster	k.	Pivot shaft
f.	Track roller	l.	Compression rod (tie rod)

9.
a.	Bolt	e.	Y-shackle
b.	U-type	f.	Center bolt
c.	Single-piece link	g.	Straight-threaded
d.	Pin and bolt		

10. Answer should include the following

a. When a track encounters an obstacle, the track rises to pass over the obstruction without raising vehicle or twisting torsion bar

b. Force is transmitted by equalizer rod to opposite torsion bar, which twists to force front of opposite track downward

c. By permitting free track action, this system and the independent main frame provide a smooth, even ride by eliminating damaging shocks and strains

ANSWERS TO TEST

11. Answer should include any three of the following

    a. Provides for more accurate dozer work

    b. Allows for better stability

    c. Provides better traction on uneven surfaces

    d. Improves riding comfort

12. Discussion should include the following

    a. Spring-type — Usually a heavy leaf-type spring; the ends rest on the track frames and the center supports center frame

    b. Stabilizer bar — Rigid bar connected to track frame and center frame; allows oscillation without spring action

13. Performance skills evaluated to the satisfaction of the instructor

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BEARINGS AND SEALS
UNIT IV

UNIT OBJECTIVE

After completing this unit, the student should be able to install bearings using various methods. The student will show this knowledge by completing job sheets and unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match to their correct definitions terms associated with bearings and seals.
2. Identify major types of bearings.
3. Select from a list basic classifications of bearings.
4. State major uses of bearings.
5. Match bearing styles to their correct functions.
6. Distinguish between advantages of plain bearings and advantages of antifriction bearings.
7. Distinguish between disadvantages of plain bearings and disadvantages of antifriction bearings.
8. List types of materials used in the construction of bearings.
9. Select from a list qualities that influence selection of bearing materials.
10. State characteristics that bearings must have to perform well.
11. State the reason for oil grooves.
12. List reasons for bearing failures.
13. List reasons for replacing bearings.
14. List items to look for when inspecting bearings.
15. Identify the most common types of grease fittings used to lubricate bearings.
16. Name other types of lubrication devices.
17. Label the parts of an antifriction ball bearing.

OBJECTIVE SHEET

18. Label the parts of an antifriction tapered roller bearing.
19. State conditions that determine load-carrying capacity of bearings.
20. State basic ball bearing race designs.
21. State basic ball bearing designs.
22. Label basic types of needle bearings.
23. Identify typical ball bearing mountings.
24. Identify typical roller bearing mountings.
25. Identify typical needle bearing mountings.
26. List causes of premature failures in bearings.
27. Distinguish between correct and incorrect methods of supporting a bearing when removing it from a shaft.
28. Arrange in order the steps used in mounting antifriction bearings.
29. Name basic types of seals.
30. List jobs that seals must perform.
31. List types of dynamic seals and static seals.
32. Identify types of noncontact seals.
33. List types of single-contact seals.
34. Select from a list types of molded packing seals.
35. Label seals, packings, and parts of a typical double-acting piston installation.
36. Demonstrate the ability to
    a. Remove a bearing using a puller.
    b. Install an antifriction bearing using an arbor press.
    c. Install a bearing using hot oil, dry oven, or electric heater method.
    d. Install a bearing using a piece of pipe.

BEARINGS AND SEALS
UNIT IV

SUGGESTED ACTIVITIES

I. Suggested activities

A. Gather equipment and materials for job sheet demonstrations.

B. Obtain transparencies.

(NOTE: Transparencies are available from AGC and CIMC.)

C. Provide students with objective sheet.

D. Discuss unit and specific objectives.

E. Provide students with information and job sheets.

F. Discuss information sheet.

G. Demonstrate and discuss procedures outlined in job sheets.

H. Show students where different types of bearings may commonly be found on a piece of equipment.

I. Give test.

J. Complete appropriate section of competency profiles.

(NOTE: Competency profiles are available from AGC and CIMC.)

II. Instructional materials

A. Objective sheet

B. Suggested activities

C. Information sheet

D. Transparency masters

1. TM #1 — Plain Bearing Oil Groove Designs
2. TM #2 — Typical Ball Bearing Mountings
3. TM #3 — Typical Roller Bearing Mountings
4. TM #4 — Typical Needle Bearing Mountings in Hydraulic Steering Pump

SUGGESTED ACTIVITIES

5. TM #5 — Single-Contact Seals

6. TM #6 — Molded Packing Seals

E. Job sheets

1. Job Sheet #1 — Remove a Bearing Using a Puller

2. Job Sheet #2 — Install an Antifriction Bearing Using an Arbor Press

3. Job Sheet #3 — Install a Bearing Using Hot Oil, Dry Oven, or Electric Heater Method

4. Job Sheet #4 — Install a Bearing Using a Piece of Pipe

F. Test

G. Answers to test

III. Unit references

A. *Fundamentals of Service: Bearings and Seals.* Moline, Illinois: Deere & Company, 1971.

B. Hendrix, Laborn J. "Bud." *Millwright Instructional Materials.* Stillwater, Oklahoma: State Department of Vocational and Technical Education/Curriculum and Instructional Materials Center, and The Associated General Contractors of America, 1980.

BEARINGS AND SEALS
UNIT IV

INFORMATION SHEET

I. Terms and definitions

A. Antifriction bearing — Bearing designed to overcome frictional resistance

B. Arbor press — Type of equipment used to press-fit bearings, gears, and other equipment

C. Axis — Real or imaginary straight line on which an object rotates or is regarded as rotating

D. Bearing — That part of a machine in which another part turns or slides

E. Flash point — Temperature at which oil may ignite

F. Friction — Resistance to motion between two contacting surfaces

G. Journal — That part of a shaft, axle, or spindle that turns in a bearing

H. Keyway — Groove cut into a shaft to accept a key

I. Key — Device to lock gears or pulleys to a shaft to prevent them from rotating on shaft

J. Labyrinth seal — Minimum-leakage seal that offers resistance to fluid flow while providing radial or axial clearance

K. Mic — Abbreviation for micrometer; in the trade, used as a verb to mean "measure with a micrometer"

EXAMPLE: Mic the bearing bore.

L. Misalignment — Improper positioning of parts or equipment

M. Parallel — Extending in the same direction; equal distance apart and never meeting

N. Plain bearing — Bearing that operates on the principle of sliding motion

O. Radially — Developing uniformly around a central axis

P. Reciprocating — Moving forward and backward alternately

Q. Sealant — Type of gasket applied as a liquid or paste

R. Splines — Ribbed or tooth-like portions of seals, bushings, pulleys, and other equipment

S. Seizure — Sudden gripping or stopping

T. Spindle — Small shaft or axle

INFORMATION SHEET

U. Sweat fit — Heating process used to expand metal

V. Temperature stick — Pencil-shaped object used to check temperature of heated metal

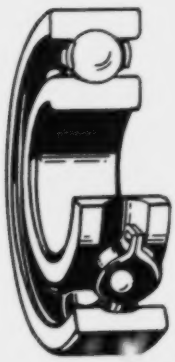
W. Tolerance — Allowable deviation from a standard

II. Major types of bearings (Figures 1-11)

A. Ball

(NOTE: Types of ball bearings include radial, angular contact, self-aligning, and duplex.)

FIGURE 1



B. Straight roller

FIGURE 2

INFORMATION SHEET

C. Tapered roller

FIGURE 3

D. Spherical roller (barrel roller)

FIGURE 4

INFORMATION SHEET

E. Ball-thrust

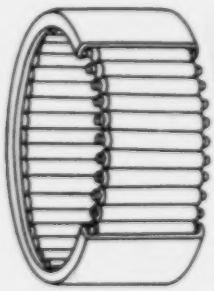
FIGURE 5

F. Concave roller

FIGURE 6

G. Radial-load needle

FIGURE 7



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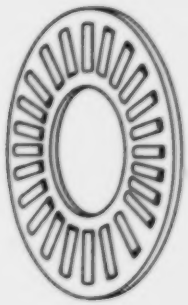
INFORMATION SHEET

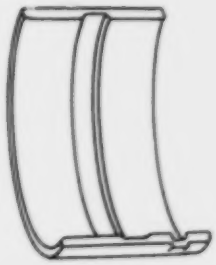
H. Thrust-load needle

FIGURE 8



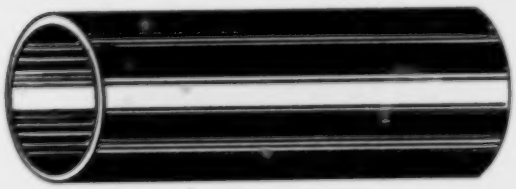
I. Split

FIGURE 9



J. Sleeve or plain (bushing)

FIGURE 10

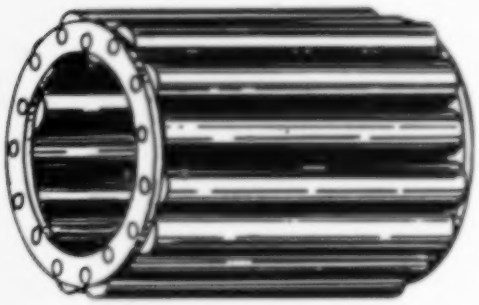


1853

INFORMATION SHEET

K. Typical journal roller

FIGURE 11



III. Basic classifications of bearings

A. Antifriction bearings

B. Plain bearings (bushings)

IV. Major uses of bearings

A. Supporting moving part

B. Reducing friction

C. Reducing wear

D. Providing a replaceable wear surface

V. Functions of bearing styles

A. Radial — Supports loads that act radially or at right angles to shaft center

B. Thrust — Supports or resists loads that act axially, parallel to, or in the direction of vehicle shaft

C. Guide — Supports and aligns members having sliding or reciprocating motion

VI. Advantages of plain bearings and antifriction bearings

A. Plain bearings (bushings)

1. Require little space 1854

INFORMATION SHEET

2. Are inexpensive
3. Operate quietly
4. Are rigidly constructed

B. Antifriction bearings

1. Operate with low friction
2. Are versatile (many designs)
3. Can be packed to reduce frequency of lubrication

VII. Disadvantages of plain bearings and antifriction bearings

A. Plain bearings (bushings)

1. Operate with high friction
2. Require frequent lubrication

B. Antifriction bearings

1. Require more space than other bearings
2. Operate noisily

VIII. Types of materials used in the construction of bearings

A. Wood
B. Plastic
C. Cast iron
D. Chilled cast iron
E. Soft steel
F. Hardened steel
G. Copper
H. Brass
I. Bronze
J. Copper/lead

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INFORMATION SHEET

K. Aluminum

L. Rubber

M. Babbit metal

N. Laminated phenolic

(NOTE: Laminated phenolic is made up of cotton fabric, asbestos, or other filler bonded with phenolic resin. It is used for camshaft gears where noise is a factor.)

O. Sintered metal

(NOTE: Sintered metal is a combination of iron, brass, bronze, graphite, phenolic material, and nylon.)

IX. Qualities that influence selection of bearing materials

A. Ability to withstand sliding contact without excessive friction

B. Strength to withstand loads without deforming

C. Ability to permit dirt or grit to become embedded without contaminating the lubricant

D. Ability to deform enough to permit distribution of load over full bearing surface

E. Ability to resist corrosion

F. Ability to conduct heat so that frictional heat will dissipate, and hot spots that may cause seizure will not develop

X. Characteristics that bearings must have to perform well

A. Means of distributing lubricant

B. Correct oil clearance to fit shaft well

C. Bearing surface compatible with shaft, lubricant, and speed of rotation

XI. Reason for oil grooves — Oil grooves are necessary to ensure that bearings receive adequate distribution of lubricant at the correct points (Transparency #1)

XII. Reasons for bearing failures

(NOTE: Always inspect damaged bearings to determine cause of failure so that cause can be remedied before replacing bearings.)

A. Dirt

B. Lack of lubrication or inferior lubricants

INFORMATION SHEET

C. Improper assembly

D. Misalignment

E. Overloading

F. Corrosion

G. Inferior material

H. Incorrect grooving

I. Incorrect clearance

XIII. Reasons for replacing bearings

A. Fatigue failure

B. Faulty oil-grooving

C. Bearing clearances too small or too large

D. Unsuitable bearing material

E. Faulty bearing design or construction

F. Breakage or damage

G. Wear

XIV. Items to look for when inspecting bearings

(NOTE: Sealed bearings can only be checked for external damage or smooth turning. When in doubt about replacing bearings, use this rule of thumb: If frequent inspections are given and bearing is easy to replace, then risk of failure may not be so great; if infrequent inspections are given and bearing is difficult to replace, then doubtful bearing should be replaced with a new one.)

A. External

1. Cracked races

2. Dented seals

3. Broken or damaged separators

4. Broken or damaged balls or rollers

5. Brownish blue or bluish black color caused by overheating

INFORMATION SHEET

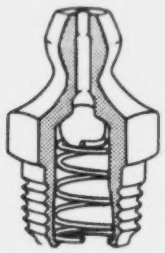
B. Internal

1. Pitted, scratched, or flaked balls on separable bearings
2. Pitted, scratched, or flaked rollers on separable bearings
3. Pitted, scratched, or flaked races on separable bearings
4. Visible pits or scratches on nonseparable bearings
5. Clicking or sticking when outer race is rotated

XV. Most common types of grease fittings used to lubricate bearings (Figures 12-16)

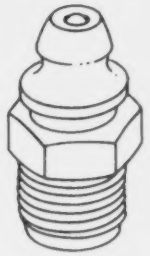
A. Conventional ball check

FIGURE 12



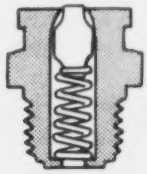
B. Pressure relief

FIGURE 13



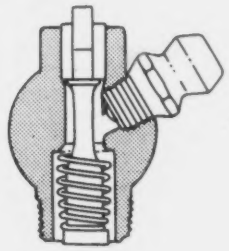
C. Button head

FIGURE 14



D. Pressure shut-off

FIGURE 15



INFORMATION SHEET

E. Hydraulic measuring

FIGURE 16

XVI. Other types of lubrication devices

A. Central grease system

(NOTE: The central grease system lubricates several bearings with a few strokes of a plunger.)

B. Oil bath splash system

(NOTE: In the oil bath splash system, rotation of gears splashes oil onto bearings.)

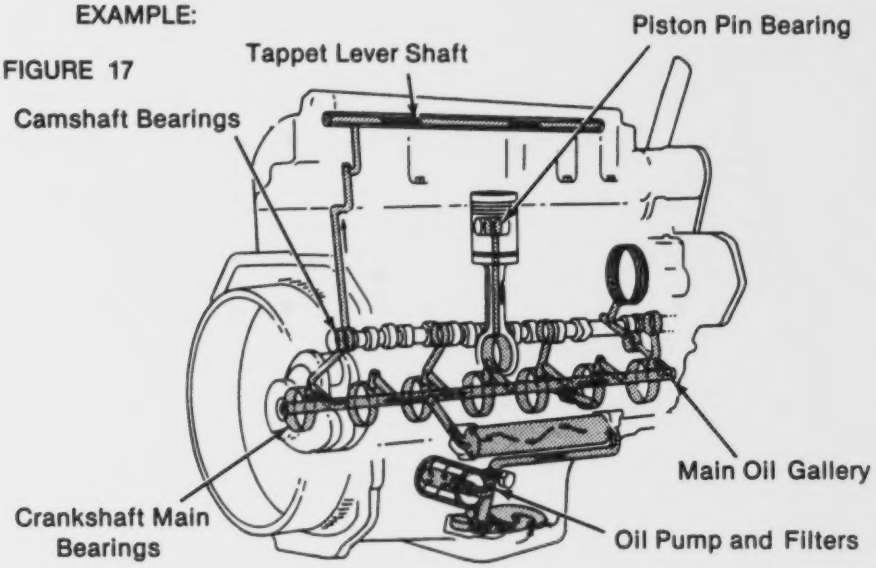
INFORMATION SHEET

C. Pressure feed system

(NOTE: The pressure feed system is a complete lubrication system that supplies oil to all the bearings in the engine system; see Figure 17.)

EXAMPLE:

FIGURE 17



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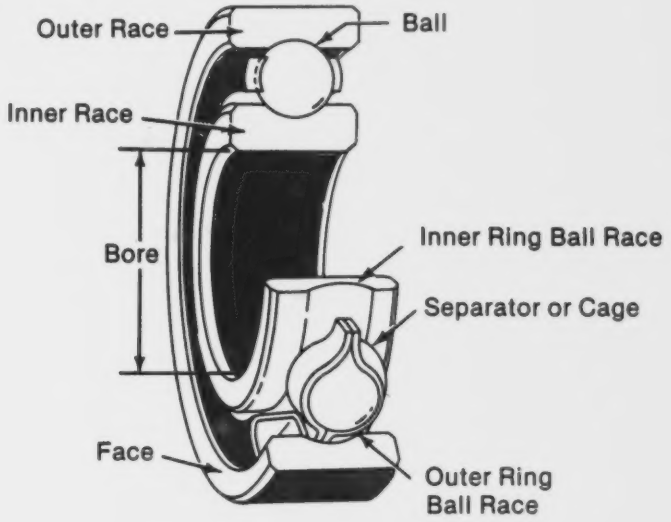
XVII. Parts of an antifriction ball bearing (Figure 18)

FIGURE 18



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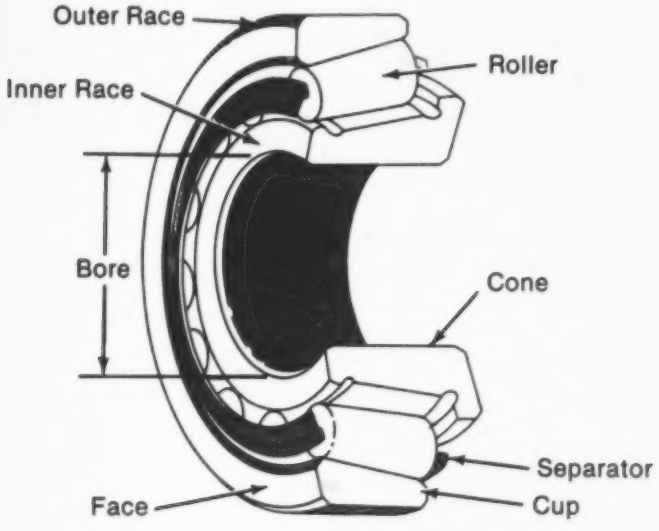
INFORMATION SHEET

XVIII. Parts of an antifriction tapered roller bearing (Figure 19)

FIGURE 19



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XIX. Conditions that determine load-carrying capacity of bearings

(NOTE: It is very important that a replacement bearing have the same load-carrying capacity as the original.)

A. Size of bearing

B. Number of rolling elements

C. Type of races

XX. Basic ball bearing race designs

A. Conrad

B. Full-type

C. Split race

D. Angular contact

XXI. Basic ball bearing designs

A. Radial-load

INFORMATION SHEET

B. Radial and thrust load

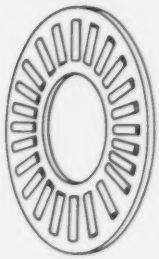
C. Self-aligning radial load

D. Thrust-load

XXII. Basic types of needle bearings (Figures 20 and 21)

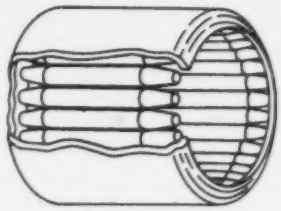
A. Thrust-load

FIGURE 20



B. Radial-load

FIGURE 21

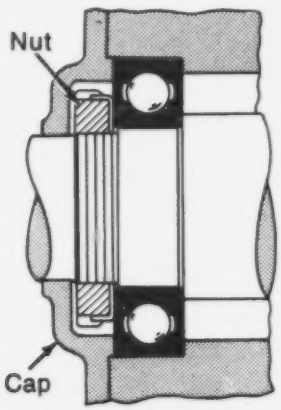


Figures 20 and 21 from Deere and Company, Moline, Illinois.

XXIII. Typical ball bearing mountings (Figures 22-29)

A. Single row radial

FIGURE 22

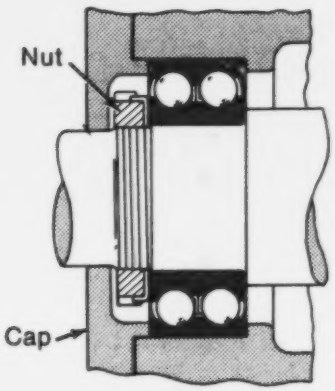


Used with permission of Deere and Company, Moline, Illinois.

INFORMATION SHEET

B. Double row radial-thrust

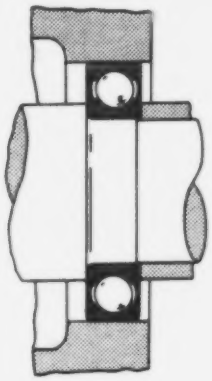
FIGURE 23



Used with permission of Deere and Company, Moline, Illinois.

C. Single row "floated"

FIGURE 24

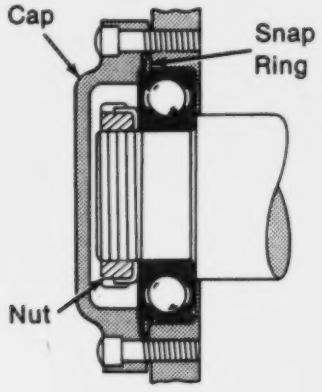


Used with permission of Deere and Company, Moline, Illinois.

INFORMATION SHEET

D. *Single row snap ring*

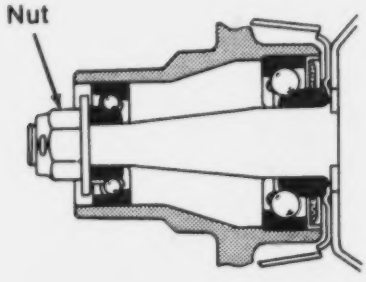
FIGURE 25



Used with permission of Deere and Company, Moline, Illinois.

E. Radial-thrust

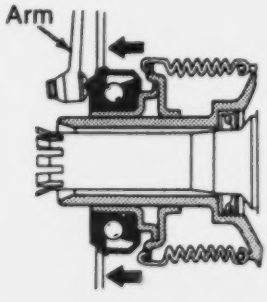
FIGURE 26



Used with permission of Deere and Company, Moline, Illinois.

F. Thrust

FIGURE 27

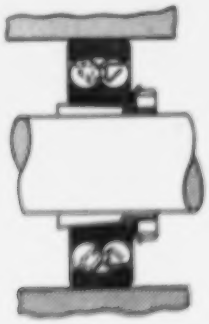


Used with permission of Deere and Company, Moline, Illinois.

INFORMATION SHEET

G. Internally self-aligning

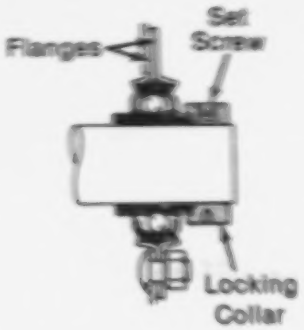
FIGURE 28



Used with permission of Deere and Company, Moline, Illinois.

H. Externally self-aligning

FIGURE 29



Used with permission of Deere and Company, Moline, Illinois.

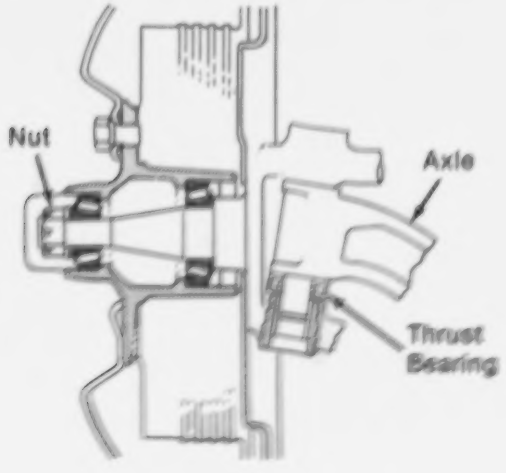
1985

INFORMATION SHEET

XXIV. Typical roller bearing mountings (Figures 30-33; Transparency #3)

A. Wheel bearing

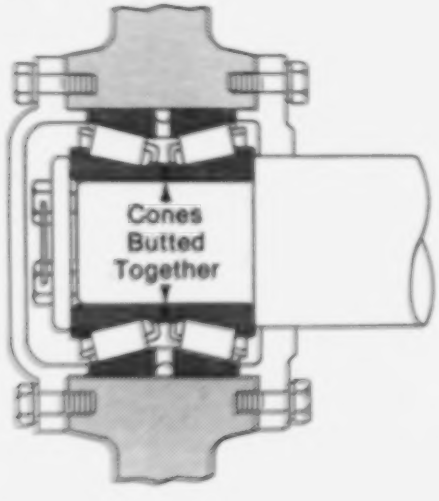
FIGURE 30



Used with permission of Deere and Company, Moline, Illinois.

B. Heavy-duty

FIGURE 31

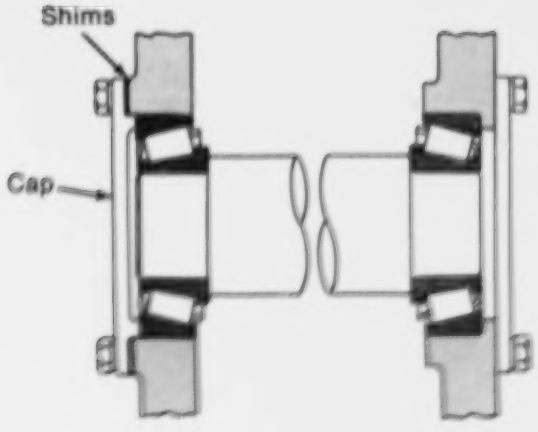


Used with permission of Deere and Company, Moline, Illinois.

INFORMATION SHEET

C. Transmission shaft

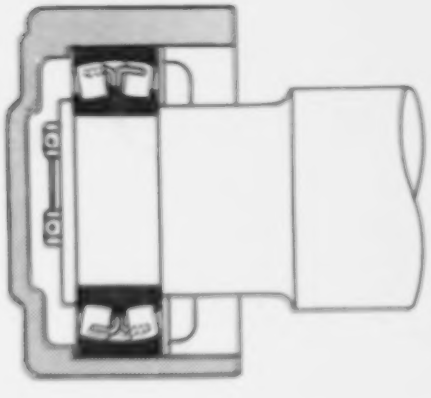
FIGURE 32



Used with permission of Deere and Company, Moline, Illinois.

D. Heavy-duty self-aligning

FIGURE 33



Used with permission of Deere and Company, Moline, Illinois.

1987

INFORMATION SHEET

XXV. Typical needle bearing mountings (Transparency #4)

A. Radial-load

(NOTE: This type of needle bearing mounting prevents radial shaft deflection.)

B. Thrust-load

(NOTE: This type of needle bearing mounting prevents axial movement.)

XXVI. Causes of premature failures in bearings

A. Contamination

B. Distortion

C. Misalignment

D. Improper fitting

E. Improper lubrication

F. Vibration while bearing is stationary

G. Electrical current passing through bearing

H. Defects in material

I. Improper servicing techniques

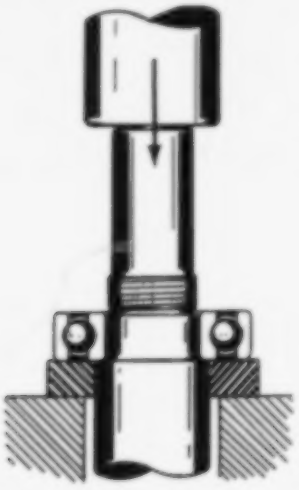
INFORMATION SHEET

XXVII. Correct and incorrect methods of supporting a bearing when removing it from a shaft (Figures 34 and 35)

(CAUTION: Care must be exercised when placing supporting blocks under the inner rings so that the force does not damage the rolling elements.)

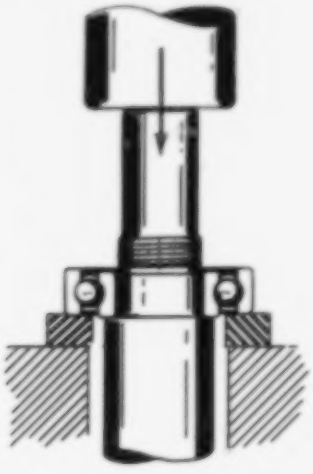
A. Correct block spacing

FIGURE 34



B. Incorrect block spacing

FIGURE 35



XXVIII. Steps used in mounting antifriction bearings

(NOTE: The preferred mounting method involves using an arbor press. The arbor-press method provides the best way of controlling alignment, support, and force.)

A. Clean shaft and bearing housing

B. Use compressed air to dry parts

(CAUTION: Use eye protection when using air compressor.)

C. Clean dirt from keyways, splines, and grooves

D. Remove burrs and slivers

E. Clean and oil bearing seats

F. Mic the shaft

INFORMATION SHEET

G. Mic the bearing bore

H. Install bearing

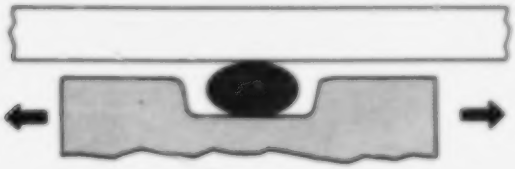
XXIX. Basic types of seals (Figures 36 and 37)

A. Dynamic

(NOTE: Dynamic seals are used to seal moving parts.)

EXAMPLE:

FIGURE 36

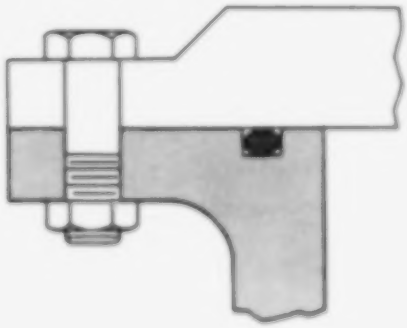


B. Static

(NOTE: Static seals are used to seal fixed parts.)

EXAMPLE:

FIGURE 37



INFORMATION SHEET

XXX. Jobs that seals must perform

(NOTE: Seals wear out faster than the parts they are used with, but they are less expensive to replace than these parts.)

A. Prevent leakage of lubricants

B. Stop flow of dirt and foreign material into system

C. Separate fluids, such as lubricant and water, from each other

D. Prevent leakage when there is small movement between parts

E. Seal rough surfaces

XXXI. Types of dynamic seals and static seals

A. Dynamic seals

(NOTE: Dynamic seals include shaft and rod seals, compression packings, and piston rings.)

1. Radial lip
2. Exclusion
3. Clearance
4. Ring
5. Face
6. Compression packings
7. Molded packings
8. Diaphragm

B. Static seals

(NOTE: Static seals are usually gaskets but may also be O-rings, packings, or sealants.)

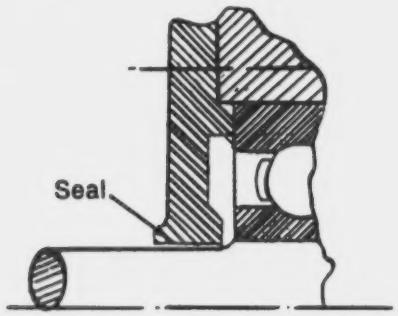
1. Nonmetallic gaskets
2. Metallic gaskets
3. Static O-rings
4. Sealants and tapes

INFORMATION SHEET

XXXII. Types of noncontact seals (Figures 38-40)

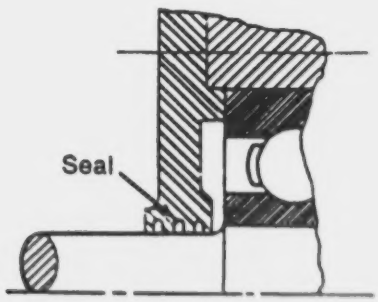
A. Plain

FIGURE 38



B. Annular groove (grease groove)

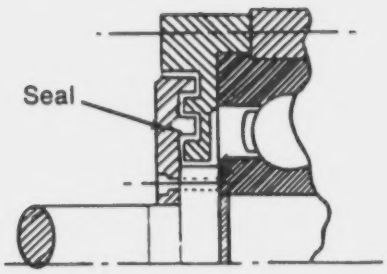
FIGURE 39



INFORMATION SHEET

C. Labyrinth

FIGURE 40



XXXIII. Types of single-contact seals (Transparency #5)

A. Felt encased

B. Laminated felt

C. Unit-type leather

D. Unit-type synthetic rubber

E. Piston ring

XXXIV. Types of molded packing seals (Transparency #6)

A. O-ring

B. V-shaped

C. U-shaped

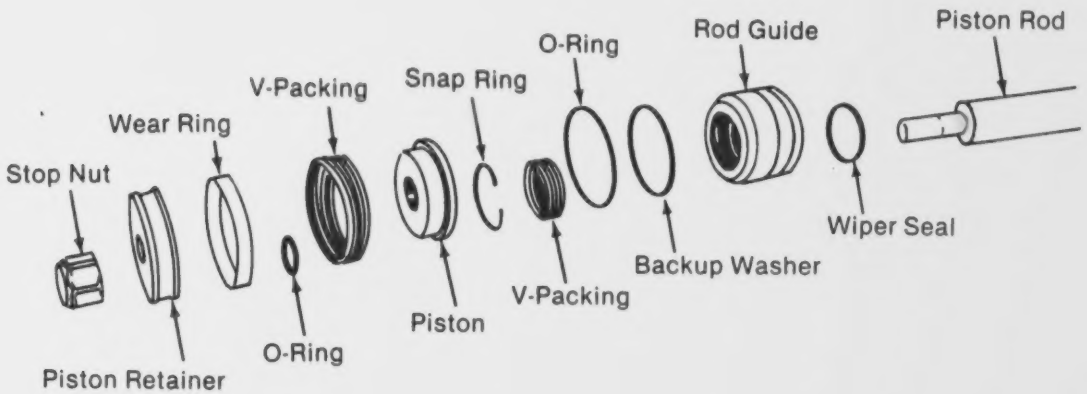
D. Rubber cup

INFORMATION SHEET

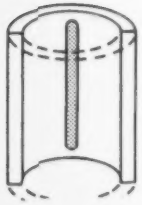
XXXV. Seals, packings, and parts of a typical double-acting piston installation (Figure 41)

(NOTE: V-ring packings are some of the most popular of all lip-type seals; they are used for low- or high-pressure applications. They can be installed on a piston [inside packed] or in a gland [outside packed].)

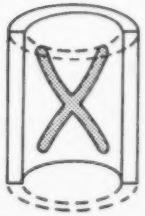
FIGURE 41



Plain Bearing Oil Groove Designs



Used in general applications.



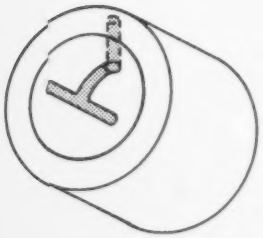
Also used in general applications.

Used for fractional horsepower motors.

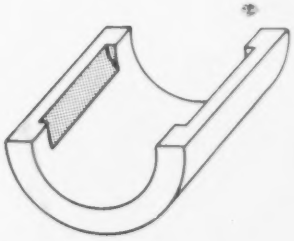
Used when oil is supplied near end of bearing.

Used for grease lubrication.

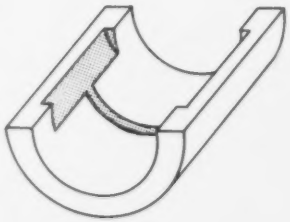
Also used for grease lubrication.



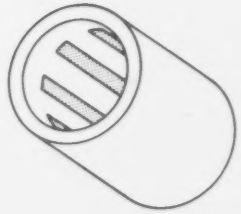
Feeder groove and axial distributing groove used for large, slow speed bearings.



Chamfered recess in split bearing distributes oil along shaft. Used in engines.



Circumferential groove and chamfered recess improves oil film cooling. Used in engine bearings.



Used for pulsating loads with limited shaft rotation.

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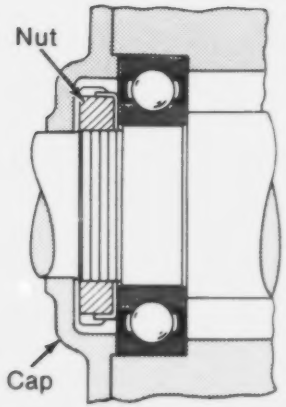
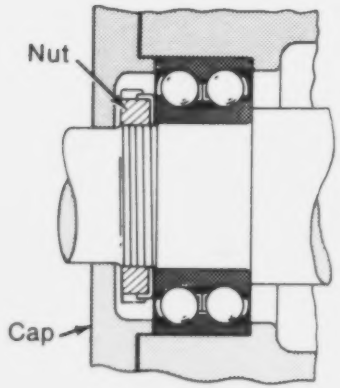
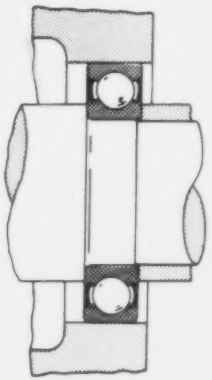
Typical Ball Bearing Mountings



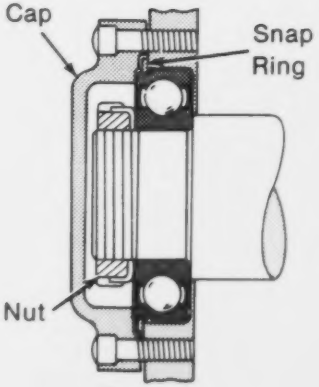
Single Row Radial



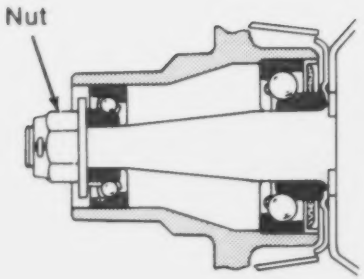
Double Row Radial-Thrust



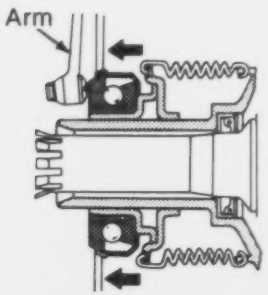
Single Row "Floated"



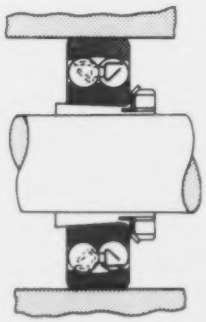
Single Row Snap Ring



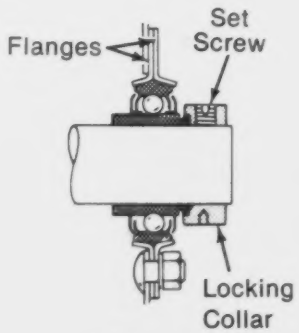
Radial-Thrust



Thrust



Internally Self-Aligning



Externally Self-Aligning

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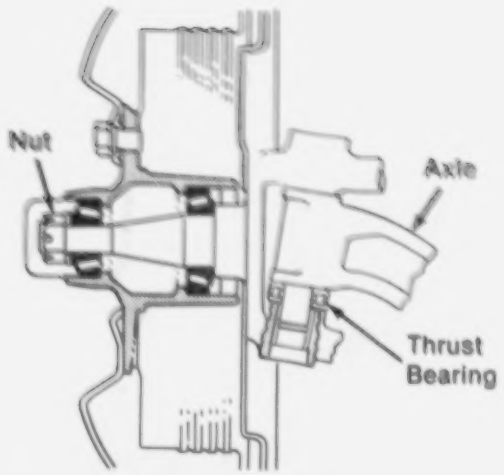
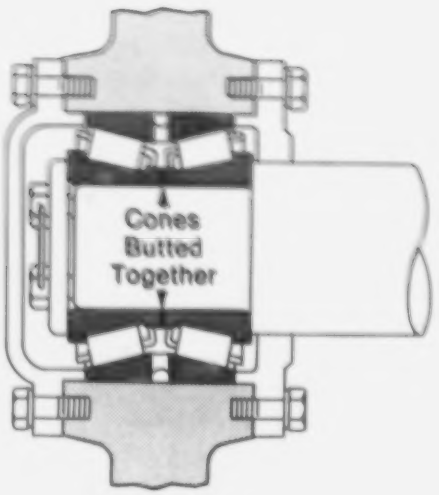
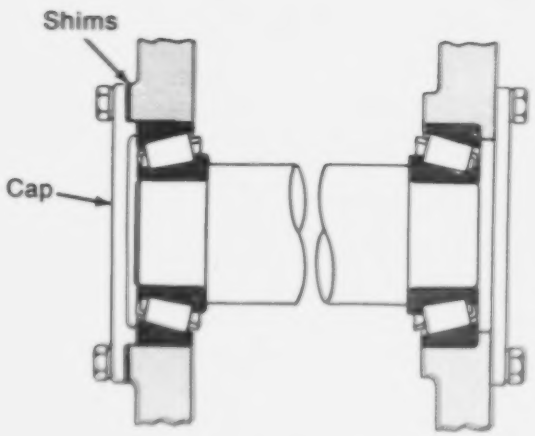
Typical Roller Bearing Mountings



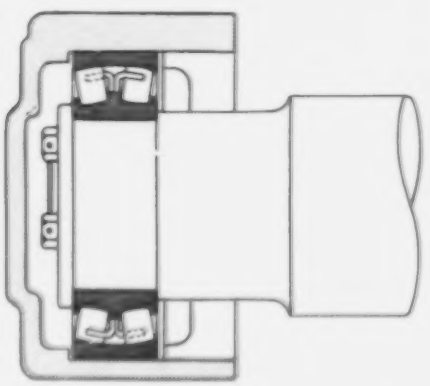
Wheel Bearing



Heavy-Duty



Transmission Shaft



Heavy-Duty
Self-Aligning

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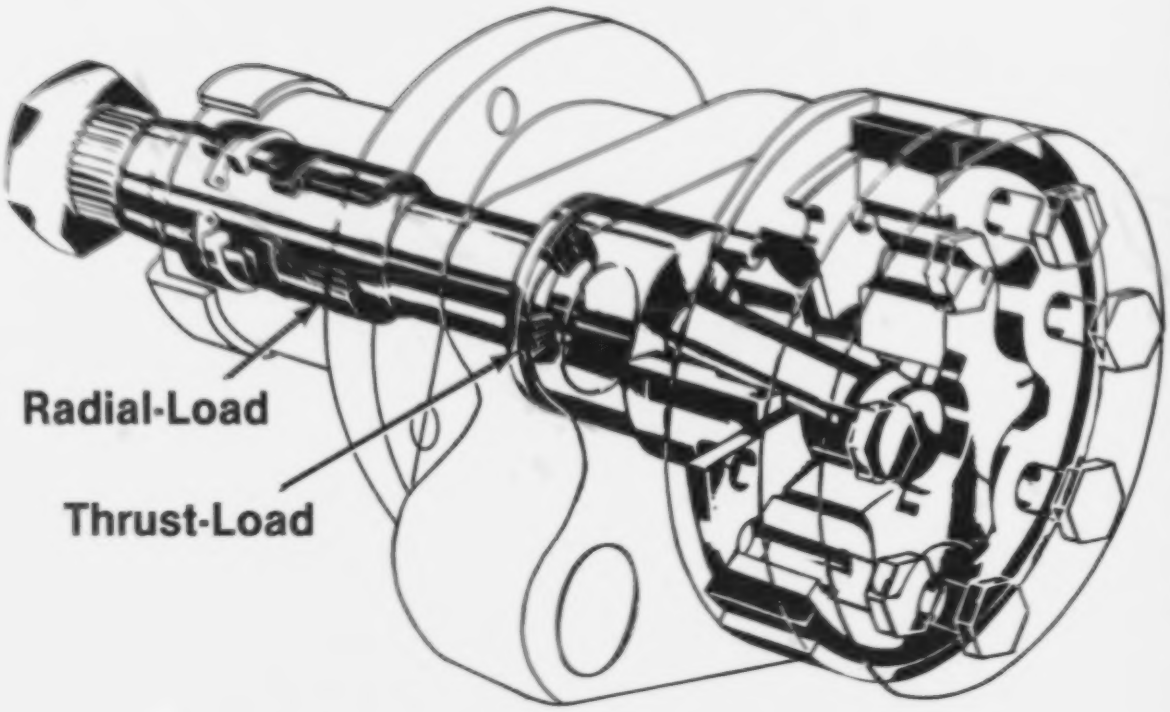
1879

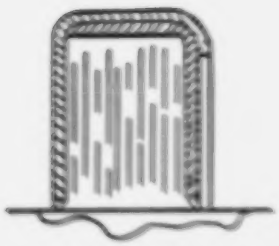
Typical Needle Bearing Mountings in Hydraulic Steering Pump



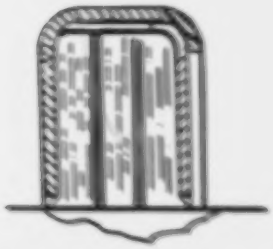
Adapted with permission of Deere and Company, Moline, Illinois.

1880

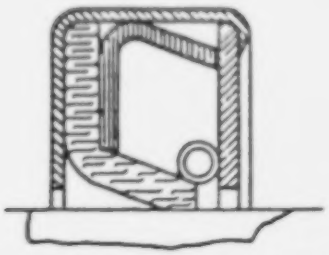
Single-Contact Seals



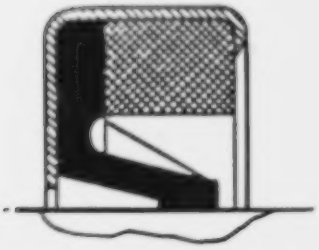
Felt Encased



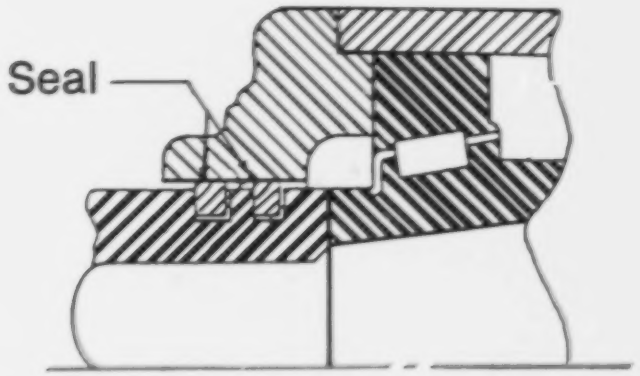
Laminated Felt



Unit-Type Leather



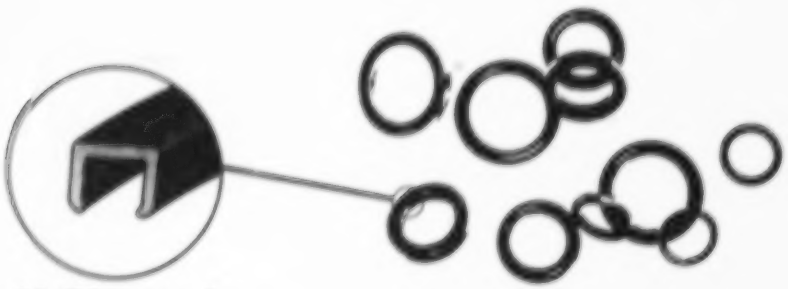
Unit-Type Synthetic Rubber



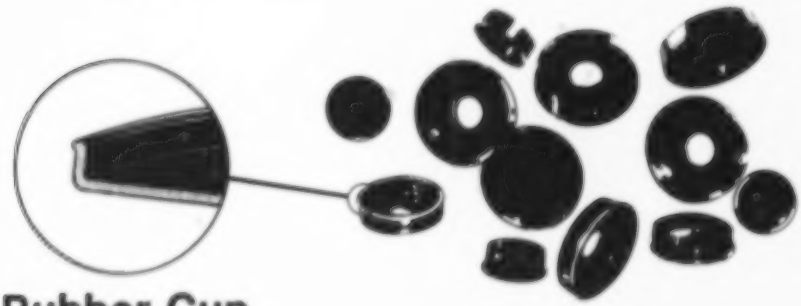
Piston Ring

1831

Molded Packing Seals

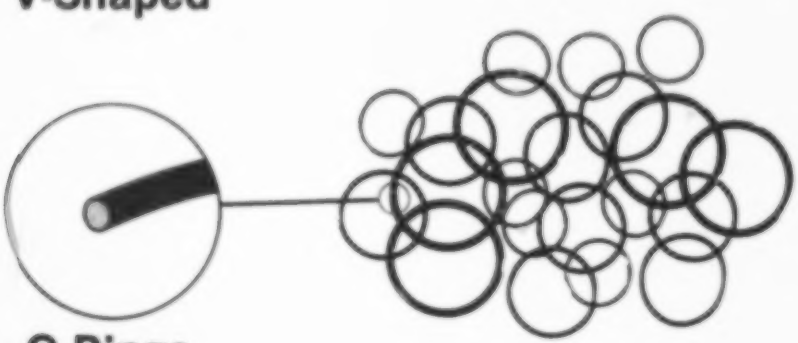


U-Shaped



Rubber Cup

V-Shaped



O-Rings

1882

BEARINGS AND SEALS
UNIT IV

JOB SHEET #1 — REMOVE A BEARING USING A PULLER

I. Equipment and materials

A. Bearing assembly

B. Screw-type external puller

C. Adjustable or open-end wrench

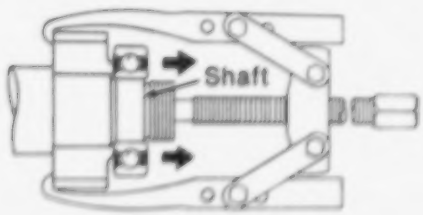
II. Procedure

A. Attach puller to bearing

B. Turn screw by hand until it is centered against end of shaft (Figure 42)

(CAUTION: Be very careful not to damage bearing when using puller.)

FIGURE 42



C. Hold puller in position until pressure is applied

D. Place wrench on head of screw and turn to apply pressure

E. Continue turning and observing movement of bearing until bearing slides free

F. Clean work area; clean and put away all tools and equipment

BEARINGS AND SEALS
UNIT IV

JOB SHEET #2 — INSTALL AN ANTIFRICTION BEARING USING AN ARBOR PRESS

I. Equipment and materials

- A. Bearing and shaft
- B. Arbor press
- C. Oil
- D. Cleaning solvent
- E. Air compressor
- F. Small brush and/or rags
- G. Shop towels
- H. Eye protection
- I. Appropriate micrometer

II. Procedure

A. Clean shaft and bearing housing

(NOTE: Cleaning solvent may be used followed by compressed air to dry bearings.)

(CAUTION: Do not let bearing spin as this may cause damage. Always wear eye protection when using compressed air.)

B. Clean dirt out of keyway, splines, and grooves (Figure 43)

FIGURE 43

JOB SHEET #2

C. Remove burrs and slivers

D. Clean and oil bearing seat

E. Mic shaft and record size

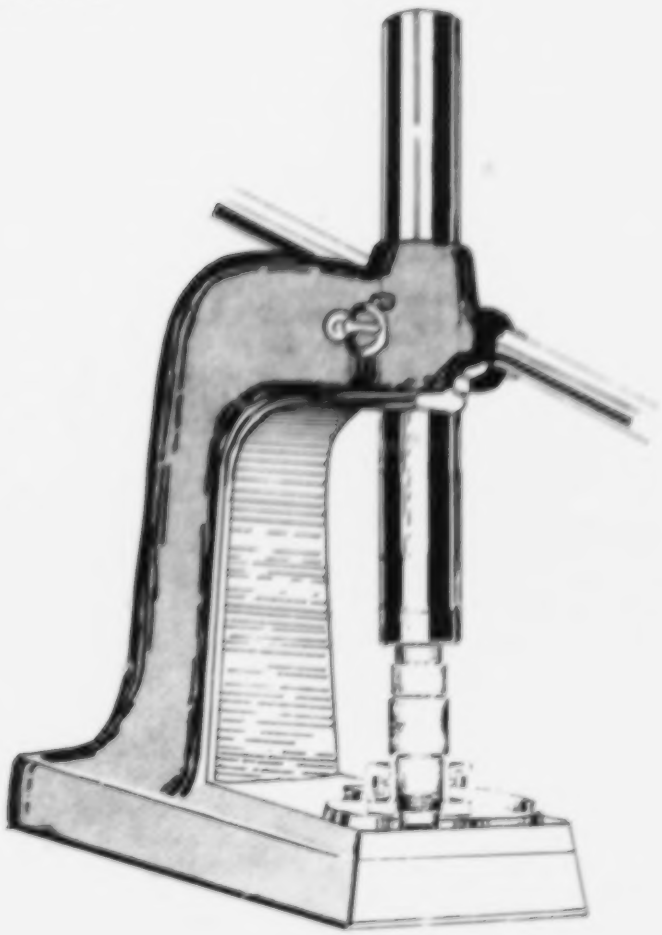
F. Mic bearing bore to determine whether bearing is a slip-on fit or whether it needs heating for installation

(NOTE: The common measurement for proper fit is 0.001 inch undersize to each 1 inch of shaft diameter.)

G. Press bearing on straight and square (Figure 44)

(CAUTION: Press only on the inner ring.)

FIGURE 44



JOB SHEET #2

H. Press bearing until it is seated against shaft or housing shoulder

I. Clean work area; clean and put away all tools and equipment

1886

BEARINGS AND SEALS
UNIT IV

JOB SHEET #3 — INSTALL A BEARING USING HOT OIL, DRY OVEN, OR ELECTRIC HEATER METHOD

I. Equipment and materials

- A. Bearing and shaft
- B. Hot oil tank, dry oven, or electric heater
- C. Thermometer
- D. Temperature stick
- E. Cleaning solvent
- F. Air compressor
- G. Small brush and/or rags
- H. Oil
- I. Shop towels
- J. Appropriate micrometer
- K. Eye protection
- L. Heat-resistant gloves
- M. Appropriate fire extinguisher

II. Procedure

- A. Clean shaft and bearing housing, using brush and cleaning solvent
- B. Dry parts with compressed air.

  (CAUTION: Do not let bearing spin as this may cause damage. Always wear eye protection when using compressed air.)
- C. Clean dirt out of keyway, splines, and grooves
- D. Remove burrs and slivers
- E. Clean and oil bearing seat
- F. Mic shaft and record size

1887

JOB SHEET #3

G. Mic bearing bore to determine whether bearing is a slip-fit or whether it needs heating for installation

(NOTE: The common measurement for proper fit is 0.001 inch undersize to each 1 inch of shaft diameter.)

H. Heat bearing to a temperature of 150°F to 400°F, depending on size of bearing and tolerance of sweat fit

(NOTE: Heating expands bearing so that it should slip over shaft with very little resistance.)

(CAUTION: Do not overheat bearing as this will affect its hardness. Caution should also be taken as to the flash point of oil being used.)

I. Use temperature stick to check temperature of bearing

J. Install bearing immediately after removing it from heat

(CAUTION: Wear protective gloves to avoid burning fingers.)

K. Slip bearing along shaft until it is seated against shaft or housing shoulder

(NOTE: Do not assume that bearing will fit.)

L. Be sure that bearing is straight and square

M. Clean work area; clean and put away all tools and equipment

BEARINGS AND SEALS
UNIT IV

JOB SHEET #4 — INSTALL A BEARING USING A PIECE OF PIPE

I. Equipment and materials

A. Bearing and shaft

B. Short piece of pipe

(NOTE: Pipe must be the same diameter as the inner ring of bearing.)

C. Hammer

D. Oil

E. Cleaning solvent

F. Air compressor

G. Small brush and/or rags

H. Hot oil tank, dry oven, or electric heater

I. Thermometer

J. Temperature stick

K. Shop towels

L. Appropriate micrometer

M. Eye protection

N. Heat-resistant gloves

O. Appropriate fire extinguisher

II. Procedure

A. Clean shaft and bearing housing, using brush and cleaning solvent

B. Dry parts with compressed air

(CAUTION: Do not let bearing spin as this may cause damage. Always wear eye protection when using compressed air.)

C. Clean dirt out of keyway, splines, and grooves

JOB SHEET #4

D. Remove burrs and slivers

E. Clean and oil bearing seat

F. Mic shaft and record size

G. Mic bearing bore to determine whether bearing will fit without heating

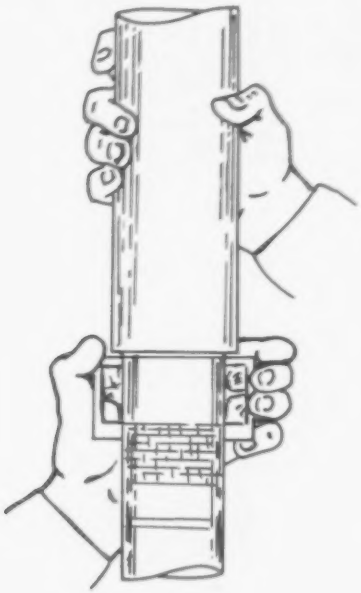
(NOTE: The common measurement for proper fit is 0.001 inch undersize to each 1 inch of shaft diameter.)

H. Heat bearing if necessary (Job Sheet #3)

I. Start bearing on shaft

J. Slip piece of pipe over shaft with one hand; while holding bearing with other hand, use a hammer-like motion to tap bearing onto shaft and into proper place (Figure 45)

FIGURE 45



K. Clean work area; clean and put away all tools and equipment

BEARINGS AND SEALS
UNIT IV

TEST

NAME _____ SCORE _____

1. Match to their correct definitions terms associated with bearings and seals. Write the correct numbers in the blanks. Terms and definitions are continued on the next page.

_____a.	Type of equipment used to press-fit bearings, gears, and other equipment	1. Keyway
_____b.	That part of a machine in which another part turns or slides	2. Parallel
_____c.	Resistance to motion between two contacting surfaces	3. Misalignment
_____d.	Groove cut into a shaft to accept a key	4. Labyrinth seal
_____e.	Minimum-leakage seal that offers resistance to fluid flow while providing radial or axial clearance	5. Friction
_____f.	Improper positioning of parts or equipment	6. Reciprocating
_____g.	Bearing that operates on the principle of sliding motion	7. Seizure
_____h.	Moving forward and backward alternately	8. Arbor press
_____i.	Ribbed or tooth-like portions of seals, bushings, pulleys, and other equipment	9. Tolerance
_____j.	Small shaft or axle	10. Bearing
_____k.	Pencil-shaped object used to check temperature of heated metal	11. Plain bearing
_____l.	Allowable deviation from a standard	12. Sealant
_____m.	Heating process used to expand metal	13. Sweat fit
_____n.	Sudden gripping or stopping	14. Spindle
_____o.	Type of gasket applied as a liquid or paste	15. Radially
_____p.	Developing uniformly around a central axis	16. Temperature stick
_____q.	Extending in the same direction; equal distance apart and never meeting	17. Splines

TEST

_____r. Abbreviation for micrometer; in the trade, used as a verb to mean "measure with a micrometer"

_____s. Device to lock gears or pulleys to a shaft to prevent them from rotating on shaft

_____t. That part of a shaft, axle, or spindle that turns in a bearing

_____u. Temperature at which oil may ignite

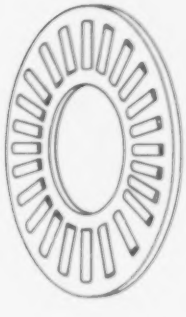
_____v. Real or imaginary straight line on which an object rotates or is regarded as rotating

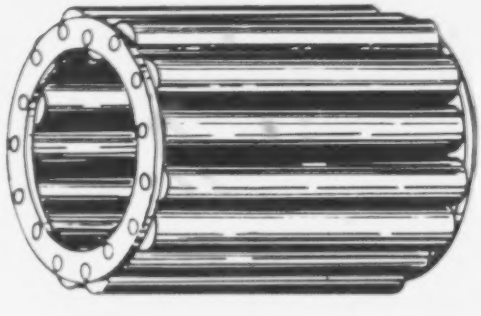
_____w. Bearing designed to overcome frictional resistance

18. Axis
19. Flash point
20. Mic
21. Key
22. Antifriction bearing
23. Journal

2. Identify major types of bearings. Write the correct names in the blanks.

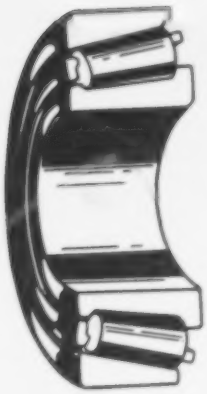
Ball
Split
Spherical roller (barrel roller)
Straight roller
Ball-thrust
Typical journal roller
Concave roller
Radial-load needle
Sleeve or plain (bushing)
Thrust-load needle
Tapered roller



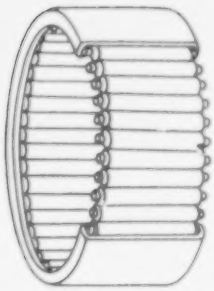


a. _____ b. _____

TEST

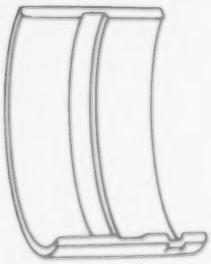


c. _____

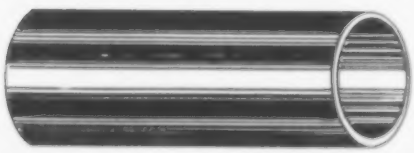


d. _____

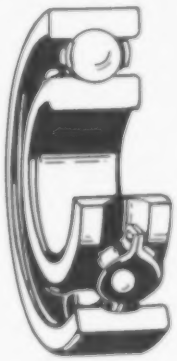
e. _____



f. _____



g. _____



h. _____

i. _____

j. _____

k. _____

1893

TEST

3. Select from the following list basic classifications of bearings. Write an "X" in the blank before each correct answer.

_____a. Plain bearings (bushings)

_____b. Friction bearings

_____c. Needle bearings

_____d. Antifriction bearings

_____e. Barrel bearings

4. State major uses of bearings.

a. _____

b. _____

c. _____

d. _____

5. Match bearing styles to their correct functions. Write the correct numbers in the blanks.

_____a. Supports or resists loads that act axially, parallel to, or in direction of vehicle shaft

_____b. Supports and aligns members having sliding or reciprocating motion

_____c. Supports loads that act radially or at right angles to shaft center

1. Guide
2. Radial
3. Thrust

6. Distinguish between advantages of plain bearings and advantages of antifriction bearings. Write "PB" in the blanks before plain bearings, and "AB" in the blanks before antifriction bearings.

_____a. Operate with low friction

_____b. Are rigidly constructed

_____c. Are inexpensive

_____d. Are versatile (many designs)

_____e. Require little space

_____f. Operate quietly

_____g. Can be packed to reduce frequency of lubrication

TEST

7. Distinguish between disadvantages of plain bearings and disadvantages of antifriction bearings. Write "PB" in the blanks before plain bearings, and "AB" in the blanks before antifriction bearings.

_____a. Operate noisily

_____b. Require more space than other bearings

_____c. Require frequent lubrication

_____d. Operate with high friction

8. List ten types of materials used in the construction of bearings.

a. _____ f. _____

b. _____ g. _____

c. _____ h. _____

d. _____ i. _____

e. _____ j. _____

9. Select from the following list qualities that influence selection of bearing materials. Write an "X" in the blank before each correct answer.

_____a. Ability to create hot spots

_____b. Ability to resist corrosion

_____c. Ability to deform enough to permit distribution of load over full bearing surface

_____d. Ability to resist misalignment

_____e. Ability to withstand sliding contact without excessive friction

_____f. Strength to withstand loads without deforming

_____g. Ability to contaminate lubricants

10. State characteristics that bearings must have to perform well.

a. _____

b. _____

c. _____

TEST

11. State the reason for oil grooves.

_____

_____

12. List five reasons for bearing failures.

a. _____

b. _____

c. _____

d. _____

e. _____

13. List four reasons for replacing bearings.

a. _____

b. _____

c. _____

d. _____

14. List three external and three internal items to look for when inspecting bearings.

a. External

1) _____

2) _____

3) _____

b. Internal

1) _____

2) _____

3) _____

TEST

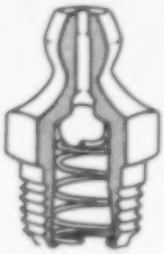
15. Identify the most common types of grease fittings used to lubricate bearings. Write the correct names in the blanks.

Conventional ball check
Button head
Pressure relief
Hydraulic measuring
Pressure shut-off

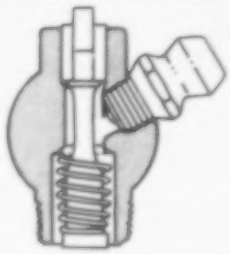
a. _____

b. _____

c. _____



d. _____



e. _____

16. Name other types of lubrication devices.

a. _____

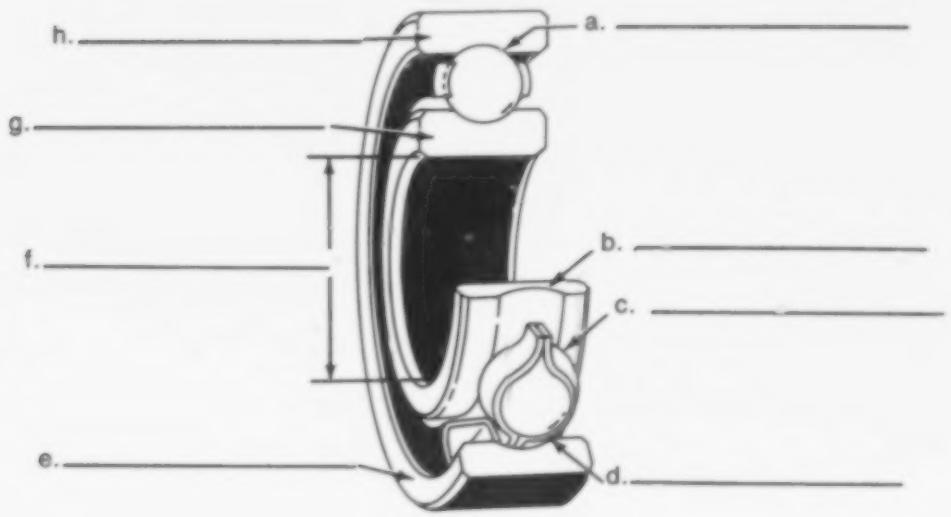
b. _____

c. _____

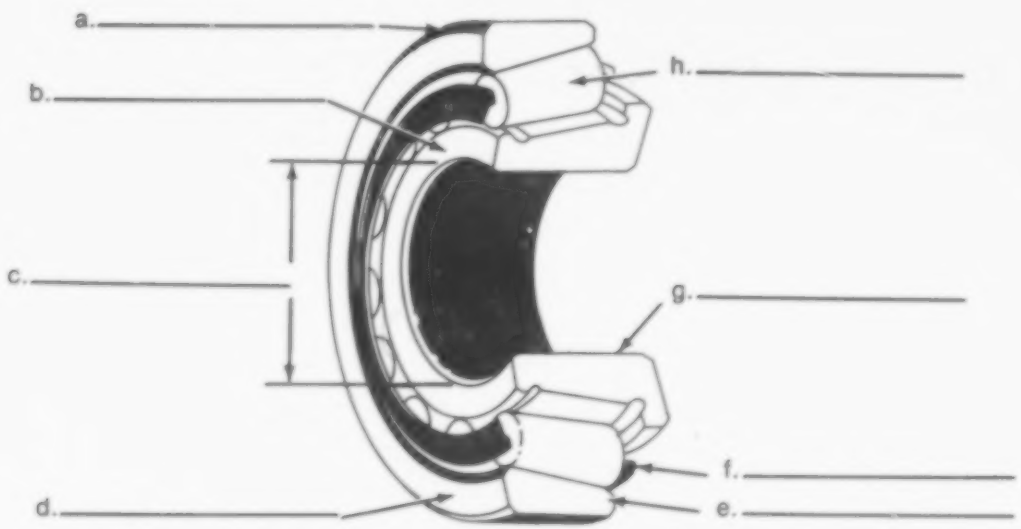
1897

TEST

17. Label the parts of the antifriction bearing illustrated below.



18. Label the parts of the antifriction tapered roller bearing illustrated below.



TEST

19. State conditions that determine load-carrying capacity of bearings.

a. _____

b. _____

c. _____

20. State basic ball bearing race designs.

a. _____

b. _____

c. _____

d. _____

21. State basic ball bearing designs.

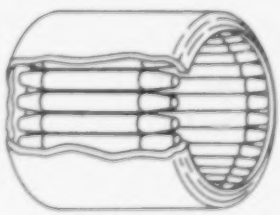
a. _____

b. _____

c. _____

d. _____

22. Label the basic types of needle bearings illustrated below.

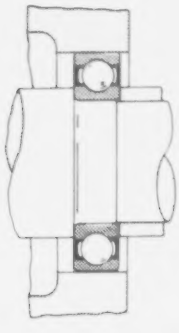


a. _____ b. _____

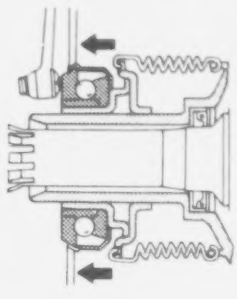
TEST

23. Identify typical ball bearing mountings. Write the correct names in the blanks.

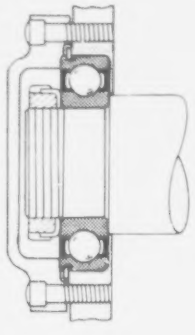
Single row radial
Radial-thrust
Single row snap ring
Single row "floated"
Thrust
Externally self-aligning
Double row radial-thrust
Internally self-aligning



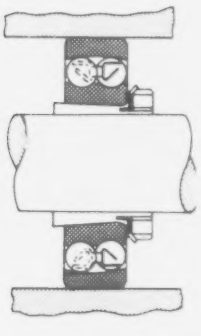
a. _____



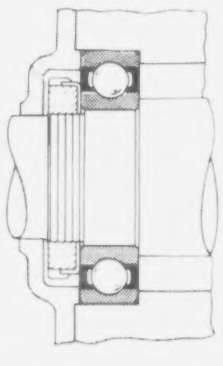
b. _____



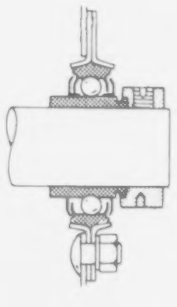
c. _____



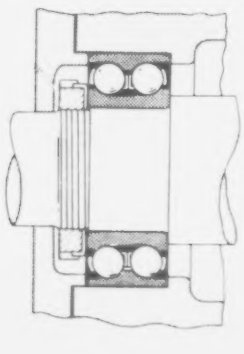
d. _____



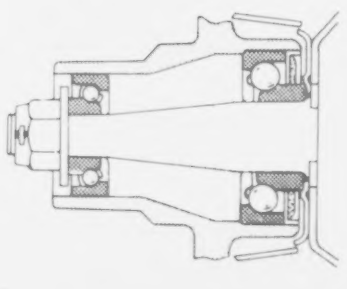
e. _____



f. _____



g. _____

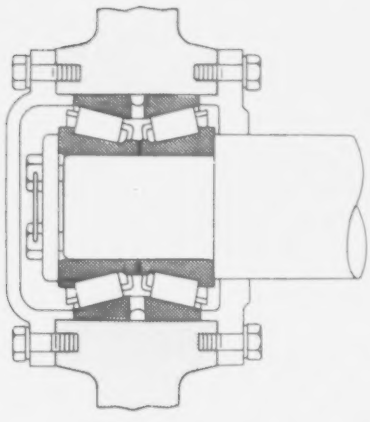


h. _____

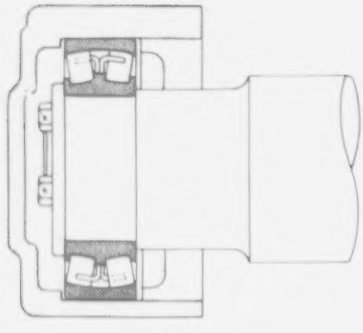
TEST

24. Identify typical roller bearing mountings. Write the correct names in the blanks.

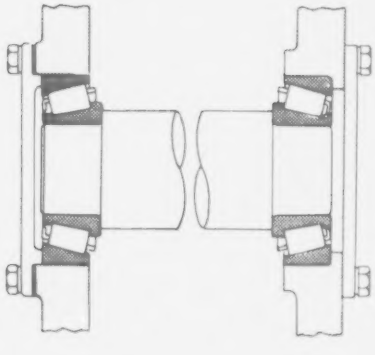
Wheel bearing
Transmission shaft
Heavy-duty self-aligning
Heavy-duty



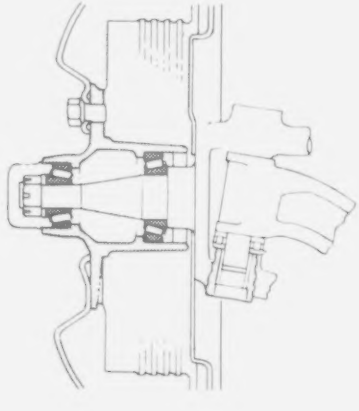
a. _____



b. _____



c. _____

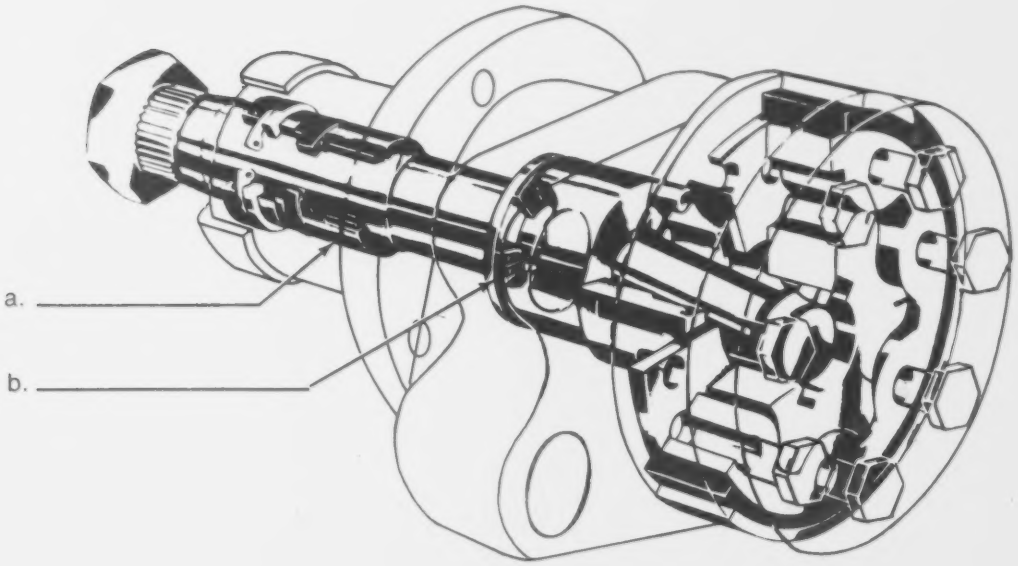


d. _____

TEST

25. Identify typical needle bearing mountings. Write the correct names in the blanks.

Radial-load **Thrust-load**



26. List five causes of premature failures in bearings.

a. _____

b. _____

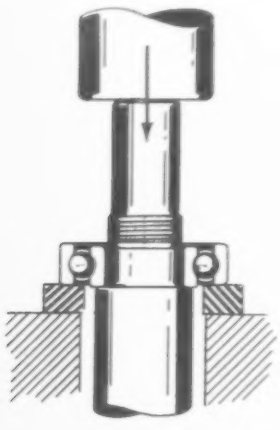
c. _____

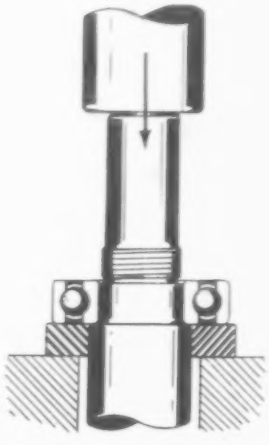
d. _____

e. _____

TEST

27. Distinguish between correct and incorrect methods of supporting a bearing when removing it from a shaft. Write an "X" in the blank beneath the correct illustration.





a. _____ b. _____

28. Arrange in order steps used in mounting antifriction bearings. Write "1" before the first step, a "2" before the second step, and so on.

_____a. Clean dirt from keyways, splines, and grooves

_____b. Mic the bearing bore

_____c. Clean shaft and bearing housing

_____d. Mic the shaft

_____e. Use compressed air to dry parts

_____f. Remove burrs and slivers

_____g. Install bearing

_____h. Clean and oil bearing seats

29. Name basic types of seals.

a. _____

b. _____

TEST

30. List three jobs that seals must perform.

a. _____

b. _____

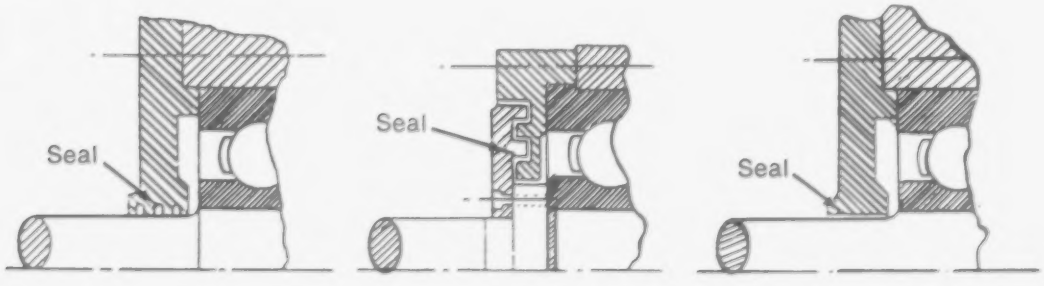
c. _____

31. List three types each of dynamic seals and static seals.

a. Dynamic	b. Static
1) _____	1) _____
2) _____	2) _____
3) _____	3) _____

32. Identify types of noncontact seals. Write the correct names in the blanks.

Annular groove (grease groove) **Labyrinth** **Plain**



a. _____ b. _____ c. _____

33. List three types of single-contact seals.

a. _____

b. _____

c. _____

TEST

34. Select from the following list types of molded packing seals. Write an "X" in the blank before each correct answer.

_____a. Rubber cup

_____b. T-ring

_____c. V-shaped

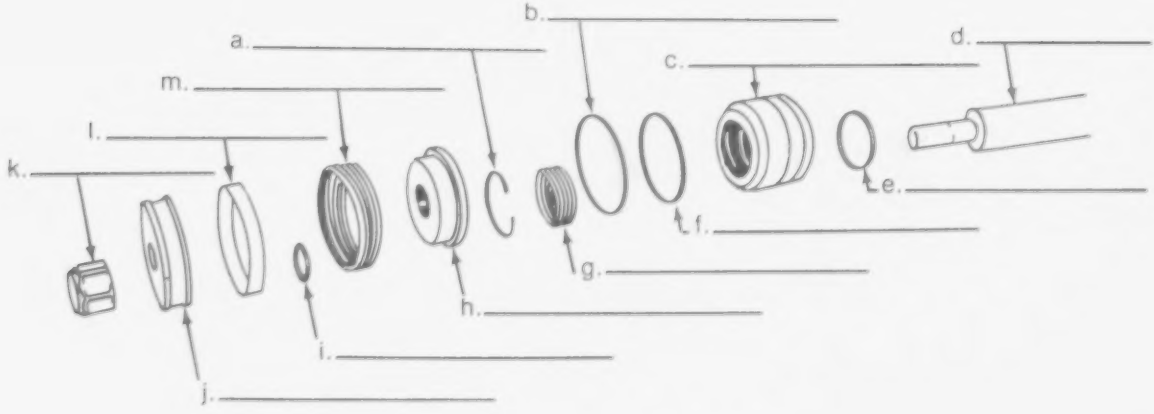
_____d. Plastic cup

_____e. U-shaped

_____f. Grease cup

_____g. O-ring

35. Label seals, packings, and parts of the typical double-acting piston installation illustrated below.



(NOTE: Test question 36 lists the job sheets. They are an important part of this test. If they have not been completed, check with your instructor.)

36. Demonstrate the ability to

a. Remove a bearing using a puller.

b. Install an antifriction bearing using an arbor press.

c. Install a bearing using hot oil, dry oven, or electric heater method.

d. Install a bearing using a piece of pipe.

BEARINGS AND SEALS
UNIT IV

ANSWERS TO TEST

1.

a.	8	g.	11	m.	13	s.	21
b.	10	h.	6	n.	7	t.	23
c.	5	i.	17	o.	12	u.	19
d.	1	j.	14	p.	15	v.	18
e.	4	k.	16	q.	2	w.	22
f.	3	l.	9	r.	20		

2.

a.	Thrust-load needle	g.	Sleeve or plain (bushing)
b.	Typical journal roller	h.	Ball
c.	Tapered roller	i.	Spherical roller (barrel roller)
d.	Radial-load needle	j.	Straight roller
e.	Ball-thrust	k.	Concave roller
f.	Split		

3. a, d

4.
a. Supporting moving part
b. Reducing friction
c. Reducing wear
d. Providing a replaceable wear surface

5.
a. 3
b. 1
c. 2

ANSWERS TO TEST

6. a. AB
   b. PB
   c. PB
   d. AB
   e. PB
   f. PB
   g. AB

7. a. AB
   b. AB
   c. PB
   d. PB

8. Answer should include any ten of the following

   a. Wood
   b. Plastic
   c. Cast iron
   d. Chilled cast iron
   e. Soft steel
   f. Hardened steel
   g. Copper
   h. Brass
   i. Bronze
   j. Copper/lead
   k. Aluminum
   l. Rubber
   m. Babbit metal
   n. Laminated phenolic
   o. Sintered metal

9. b, c, e, f

10. a. Means of distributing lubricant
    b. Correct oil clearance to fit shaft well
    c. Bearing surface compatible with shaft, lubricant, and speed of rotation

11. Oil grooves are necessary to ensure that bearings receive adequate distribution of lubricant at the correct points

ANSWERS TO TEST

12. Answer should include any five of the following

    a. Dirt

    b. Lack of lubrication or inferior lubricants

    c. Improper assembly

    d. Misalignment

    e. Overloading

    f. Corrosion

    g. Inferior material

    h. Incorrect grooving

    i. Incorrect clearance

13. Answer should include any four of the following

    a. Fatigue failure

    b. Faulty oil-grooving

    c. Bearing clearances too small or too large

    d. Unsuitable bearing material

    e. Faulty bearing design or construction

    f. Breakage or damage

    g. Wear

14. Answer should include any three of the following external and internal items

    a. External

        1) Cracked races

        2) Dented seals

        3) Broken or damaged separators

        4) Broken or damaged balls or rollers

ANSWERS TO TEST

5) Brownish blue or bluish black color caused by overheating

b. Internal

1) Pitted, scratched, or flaked balls on separable bearings

2) Pitted, scratched, or flaked rollers on separable bearings

3) Pitted, scratched, or flaked races on separable bearings

4) Visible pits or scratches on nonseparable bearings

5) Clicking or sticking when outer race is rotated

15. a. Button head

b. Hydraulic measuring

c. Pressure relief

d. Conventional ball check

e. Pressure shut-off

16. a. Central grease system

b. Oil bath splash system

c. Pressure feed system

17. a. Ball
b. Inner ring ball race
c. Separator or cage
d. Outer ring ball race
e. Face
f. Bore
g. Inner race
h. Outer race

18. a. Outer race
b. Inner race
c. Bore
d. Face
e. Cup
f. Separator
g. Cone
h. Roller

ANSWERS TO TEST

19. a. Size of bearing
    b. Number of rolling elements
    c. Type of races

20. a. Conrad
    b. Full-type
    c. Split race
    d. Angular contact

21. a. Radial-load
    b. Radial and thrust load
    c. Self-aligning radial load
    d. Thrust-load

22. a. Thrust-load
    b. Radial-load

23. a. Single row "floated"
    b. Thrust
    c. Single row snap ring
    d. Internally self-aligning
    e. Single row radial
    f. Externally self-aligning
    g. Double row radial-thrust
    h. Radial-thrust

24. a. Heavy-duty
    b. Heavy-duty self-aligning

ANSWERS TO TEST

c. Transmission shaft

d. Wheel bearing

25. a. Radial-load

b. Thrust-load

26. Answer should include any five of the following

a. Contamination

b. Distortion

c. Misalignment

d. Improper fitting

e. Improper lubrication

f. Vibration while bearing is stationary

g. Electrical current passing through bearing

h. Defects in material

i. Improper servicing techniques

27. b

28.

a.	3	e.	2
b.	7	f.	4
c.	1	g.	8
d.	6	h.	5

29. a. Dynamic

b. Static

ANSWERS TO TEST

30. Answer should include any three of the following

    a. Prevent leakage of lubricants

    b. Stop flow of dirt and foreign material into system

    c. Separate fluids, such as lubricant and water, from each other

    d. Prevent leakage when there is small movement between parts

    e. Seal rough surfaces

31. Answer should include any three of the following dynamic and static seals

    a. Dynamic

        1) Radial lip
        2) Exclusion
        3) Clearance
        4) Ring
        5) Face
        6) Compression packings
        7) Molded packings
        8) Diaphragm

    b. Static

        1) Nonmetallic gaskets
        2) Metallic gaskets
        3) Static O-rings
        4) Sealants and tapes

32. a. Annular groove (grease groove)

    b. Labyrinth

    c. Plain

33. Answer should include any three of the following

    a. Felt encased

    b. Laminated felt

    c. Unit-type leather

    d. Unit-type synthetic rubber

    e. Piston ring

ANSWERS TO TEST

34. a, c, e, g

35.

a.	Snap ring	h.	Piston
b.	O-ring	i.	O-ring
c.	Rod guide	j.	Piston retainer
d.	Piston rod	k.	Stop nut
e.	Wiper seal	l.	Wear ring
f.	Backup washer	m.	V-packing
g.	V-packing		

36. Performance skills evaluated to the satisfaction of the instructor

ARC WELDING
UNIT I

UNIT OBJECTIVE

After completing this unit, the student should be able to identify parts of the welding process and types of welds, and perform various welding jobs. The student will show this knowledge by completing job sheets and unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match terms associated with arc welding to their correct definitions.
2. Write meanings of abbreviations associated with arc welding.
3. State safety precautions to observe when welding.
4. Name types of arc-welding machines.
5. Select from a list common tools and equipment used in arc welding.
6. Match to their correct definitions terms associated with welding materials.
7. List types of electrodes.
8. Select from a list common sizes of electrodes used in arc welding.
9. Interpret meanings of numbers in the AWS electrode classification system.
10. Distinguish between reverse and straight polarity.
11. Select from a list factors that determine correct polarities to use.
12. Select from a list purposes of electrode flux.
13. List factors to consider when selecting electrodes.
14. Describe effects of raising and lowering welding machine amperes.
15. Name methods of striking an arc.
16. Select from a list characteristics of proper arc length.
17. Identify parts of the welding process.
18. Match types of welds to their correct descriptions.

OBJECTIVE SHEET

19. Label types of welds.
20. Label types of weld joints.
21. Label parts of groove and fillet welds.
22. List positions used in arc welding.
23. List reasons for poor welds.
24. List types of electrode motions (rod manipulations).
25. State characteristics of a good weld.
26. Match elements of welding symbols to their correct descriptions.
27. Draw symbols showing location of weld.
28. Identify basic weld symbols.
29. Distinguish between correct and incorrect drawings of symbols with one vertical side.
30. Label supplementary symbols.
31. Interpret finish symbols used with contour symbols.
32. Demonstrate the ability to
    a. Start, stop, and restart a bead.
    b. Construct a pad weld.
    c. Construct a butt weld.
    d. Construct a lap-joint fillet weld in the overhead position.
    e. Construct a T-joint fillet weld in the vertical up position.
    f. Construct a square-groove butt-joint weld in the vertical down position.

ARC WELDING
UNIT I

SUGGESTED ACTIVITIES

I. Suggested activities

A. Order films and other materials that may be needed for reference and motivation. Be sure to obtain an *Electrode Guidebook*.

(NOTE: Manufacturers and equipment dealers are the best sources for these materials.)

B. Obtain transparencies.

(NOTE: Transparencies are available from AGC and CIMC.)

C. Provide students with objective sheet.

D. Discuss unit and specific objectives.

E. Provide students with information and job sheets.

F. Discuss information sheet.

G. Gather equipment and materials needed for job sheet demonstrations.

H. Demonstrate and discuss procedures outlined in job sheets.

I. Discuss the different lens-shade selections for welding shield or helmet. (Table 1)

EXAMPLE:

TABLE 1

LENS—SHADE SELECTOR	
Shade Number	**Type of Operation**
2	Soldering
3 or 4	Torch brazing
3 or 4 3 or 5 5 or 6	Oxygen cutting 0 to 1 inch 1 to 6 inches 6 inches and over
4 or 5 5 or 6 6 or 8	Gas welding 0 to 1/3 inch 1/8 to 1/2 inch 1/2 inch and over
9 to 14	Shielded metal-arc welding 1/16-, 3/4-, 1/8-, 5/32-inch electrodes
9 to 14	Gas-metal arc welding
9 to 14	Gas-tungsten arc welding nonferrous gas-metal arc welding 1/16-, 3/32-, 1/8-, 5/32-inch electrodes
9 to 14	Gas-tungsten arc welding (ferrous), gas-metal arc welding (ferrous) 1/16-, 3/32-, 1/8-, 5/32-inch electrodes

SUGGESTED ACTIVITIES

J. Give test.

K. Complete appropriate section of competency profiles.

(NOTE: Competency profiles are available from AGC and CIMC.)

II. Instructional materials

A. Objective sheet

B. Suggested activities

C. Information sheet

D. Transparency masters

1. TM #1 — Common Tools and Equipment Used in Arc Welding
2. TM #2 — Welding Circuit
3. TM #3 — AWS Electrode Classification System
4. TM #4 — Parts of the Welding Process
5. TM #5 — Positions Used in Arc Welding
6. TM #6 — Characteristics of a Good Weld
7. TM #7 — Elements of Welding Symbol
8. TM #8 — Standard Location of Welding Symbol Elements
9. TM #9 — Application of Fillet Welding Symbol
10. TM #10 — Application of Fillet Welding Symbol (Continued)
11. TM #11 — Application of Plug Welding Symbol
12. TM #12 — Application of Slot Welding Symbol
13. TM #13 — Application of Spot Welding Symbol
14. TM #14 — Application of Spot Welding Symbol (Continued)
15. TM #15 — Application of Seam Welding Symbol
16. TM #16 — Application of Seam Welding Symbol (Continued)
17. TM #17 — Application of Square-Groove Welding Symbol

SUGGESTED ACTIVITIES

18. TM #18 — Application of V-Groove Welding Symbol
19. TM #19 — Application of Bevel-Groove Welding Symbol
20. TM #20 — Application of U-Groove Welding Symbol
21. TM #21 — Application of J-Groove Welding Symbol
22. TM #22 — Application of Flared V-Groove Welding Symbol
23. TM #23 — Application of Flared Bevel-Groove Welding Symbol
24. TM #24 — Application of Edge-Flange Welding Symbol
25. TM #25 — Application of Corner-Flange Welding Symbol
26. TM #26 — Designation of Location and Extent of Fillet Welds
27. TM #27 — Designation of Location and Extent of Fillet Welds (Continued)
28. TM #28 — Designation of Extent of Welding
29. TM #29 — Application of Dimensions to Spot Welding Symbols
30. TM #30 — Application of Dimensions to Spot Welding Symbols (Continued)
31. TM #31 — Application of Dimensions to Seam Welding Symbols
32. TM #32 — Application of Dimensions to Seam Welding Symbols (Continued)

E. Job sheets

1. Job Sheet #1 — Start, Stop, and Restart a Bead
2. Job Sheet #2 — Construct a Pad Weld
3. Job Sheet #3 — Construct a Butt Weld
4. Job Sheet #4 — Construct a Lap-Joint Fillet Weld in the Overhead Position
5. Job Sheet #5 — Construct a T-Joint Fillet Weld in the Vertical Up Position
6. Job Sheet #6 — Construct a Square-Groove Butt-Joint Weld in the Vertical Down Position

SUGGESTED ACTIVITIES

F. Test

G. Answers to test

III. Unit references

A. Hendrix, Laborn J., "Bud." *Millwright Instructional Materials.* Stillwater, Oklahoma: State Department of Vocational and Technical Education/Curriculum and Instructional Materials Center, and The Associated General Contractors of America, 1980.

B. Hendrix, Laborn J., "Bud." *Heavy Equipment Operator Instructional Materials, Vol. I.* Stillwater, Oklahoma: State Department of Vocational and Technical Education/Curriculum and Instructional Materials Center, and The Associated General Contractors of America, 1981.

C. Jefferson, T.B. *The Welding Encyclopedia.* Morton Grove, Illinois: Monticello Books, 1968.

D. *Symbols for Welding and Nondestructive Testing.* Miami, Florida: American Welding Society, Inc., 1979.

ARC WELDING
UNIT I

INFORMATION SHEET

I. Terms and definitions

A. Arc — Flow of current across a narrow gap, usually from tip of electrode to base metal

B. Arc length — Distance from end of electrode to point where arc makes contact with work surface

C. Arc welding — Joining of two or more pieces of metal by fusion process

(NOTE: Arc welding is sometimes referred to as *shielded metal-arc welding, SMAW,* or *stick welding.*)

D. Bevel — Angular cut made on the vertical edge of base metal to allow better weld penetration

E. Butt joint — Weld between two metal joints on the same plane

F. Crater — Depression at termination of weld

G. Ductile — Capable of being drawn or stretched

H. Electrode — Metal rod that conducts a current from electrode holder to base metal

(NOTE: The metal rod melts and deposits metal in a bead.)

I. Flux — Coating on outside of electrode; chemical used to promote fusion during welding process

J. Fusion process — Process of heating metal to a molten state and allowing it to cool

(NOTE: In arc welding, the heat is produced by the electric arc.)

K. Gaseous shield — Gas given off by melting of electrode flux

L. Heat line (heat-affected zone) — That part of base metal altered by heat from welding, brazing, or cutting operations

M. Lead — Cables leading from ground clamp and holder to machine

N. Low-hydrogen electrode — Electrode with low hydrogen content; used when cracking is a potential problem

INFORMATION SHEET

O. Malleable — Capable of being worked into a different shape or form

P. Pass — Single longitudinal progression of a welding operation along a joint or weld deposit

Q. Penetration — Distance from original surface of base metal to that point at which fusion ceases

R. Polarity — Condition of being positive (+) or negative (−), as the ends of a magnet or electrical mechanism

S. Puddle — Portion of a weld that is molten at the place heat is applied

T. Rippled — Lightly ruffled or covered with small waves

U. Slag inclusion — Nonmetallic porous material trapped in weld metal or between weld metal and base metal

V. Wire core — Metal center of electrode

II. Abbreviations associated with arc welding and their meanings

A. AC — Alternating current; electric current that reverses its direction at regular intervals

B. AWS — American Welding Society

C. DC — Direct current; electric current flowing in one direction only and mostly constant in value

D. OSHA — Occupational Safety and Health Act

E. psi — Pounds per square inch

III. Safety precautions to observe when welding

(NOTE: Observe OSHA safety rules.)

A. Do not look at arc or reflection without eye protection

B. Do not wear shield or helmet that is in bad condition

C. Do not chip slag without wearing safety goggles

D. Wear proper protective clothing

EXAMPLES: Welder's leather vest or jacket, long-sleeved shirt with collar and cuffs buttoned, leather gloves, high-topped shoes or boots

INFORMATION SHEET

E. Do not strike an arc until you have taken all safety precautions

F. Do not weld around combustible or flammable materials

G. Do not pick up hot metals with bare hands

H. Be sure that confined areas are properly ventilated

I. Disconnect plug before checking welding machine

J. Do not leave electrode holder on welding table or in direct contact with grounded metal

K. Do not use worn or frayed cables

L. Be sure that floor is dry; do not stand in water when welding

M. Keep work area clean

N. Keep tools and materials in proper locations

O. Dispose of electrode stubs properly

IV. Types of arc-welding machines

A. Alternating-current (AC) transformer welder

(NOTE: The welding current reverses direction of flow 120 times per second.)

B. Direct-current (DC) welder

(NOTE: The welding current flows in one direction.)

C. Motor generator

(NOTE: The motor generator produces DC current.)

D. Engine generator

(NOTE: The engine generator can produce either AC or DC current.)

E. AC/DC transformer rectifier

(NOTE: This welder, which is supplied by an AC power source, can be switched to produce either AC or DC welding current.)

INFORMATION SHEET

V. Common tools and equipment used in arc welding (Transparency #1)

A. Welding machine

B. Electrode holder with lead

C. Ground clamp with lead

D. Shield or helmet

E. Leather gloves

F. Chipping hammer

G. Safety goggles

H. Wire brush

I. Electrode

J. Protective clothing

VI. Terms and definitions associated with welding materials

A. Alloy — Mixture of two or more elements, of which at least one is a metal

B. Aluminum — Bluish silver-white, malleable, ductile, light, trivalent metallic element

C. Base metal — Metal to be cut or welded

D. Cast iron — Commercial alloy of iron, carbon, and silicon that is cast in a mold and is hard, brittle, nonmalleable, and incapable of being hammer-welded

E. Low-carbon steel — Steel containing 0.2 percent or less carbon

F. Mild steel — Steel containing from 0.2 to 0.5 percent carbon

G. Vanadium — Hardest known metal; used for making very strong alloy steels with manganese or chromium

VII. Types of electrodes

(NOTE: Electrodes most frequently used are made of mild steel.)

A. Mild steel

B. Low-alloy steel

INFORMATION SHEET

C. Nickel steel

D. Chromium/molybdenum steel

E. Manganese/molybdenum steel

F. Nickel/manganese/molybdenum steel

G. Nickel/molybdenum/vanadium steel

H. Aluminum

I. Copper aluminum (aluminum bronze)

J. Lead-bronze

K. Phosphor bronze

VIII. Common sizes of electrodes used in arc welding

(NOTE: Electrodes range in size from 1/16 to 5/16 inch.)

A. 3/32 inch

B. 1/8 inch

C. 5/32 inch

D. 3/16 inch

IX. Meanings of numbers in the AWS electrode classification system (Transparency #3)

EXAMPLE: E-6021

A. E — Electric arc welding

B. First two digits (60) — Minimum tensile strength deposited in thousands of pounds per square inch

C. Third digit (2) — Welding position

1. One — Indicates all positions
2. Two — Indicates flat and horizontal only
3. Three — Indicates flat only

INFORMATION SHEET

D. Fourth or last digit (1) — Special characteristics and uses of the electrode (Table 2)

EXAMPLE:

TABLE 2

Last-Digit Characteristics

Last Digit	Power Supply	Arc Action	Type of Flux	Penetration Characteristics
0	10, DCRP (+)	Digging	10, organic	10, deep
	20, AC or DC		20, mineral	20, medium
1	AC or DCRP (+)	Digging	Organic	Deep
2	AC or DC	Medium	Ductile	Medium
3	AC or DC	Soft	Ductile	Light
4	AC or DC	Soft	Ductile	Light
5	DCRP (+)	Medium	Low hydrogen	Medium
6	AC or DCRP (+)	Medium	Low hydrogen	Medium
7	AC or DC	Soft	Mineral	Medium
8	AC or DCRP (+)	Medium	Low hydrogen	Medium

(Source: T.B. Jefferson, *The Welding Encyclopedia*, p. E-4, Monticello Books, Lake Zurich, Illinois, 1968.)

X. Reverse and straight polarity (Transparency #2)

A. Reverse (+) — Current flows from base metal to electrode

B. Straight (−) — Current flows from electrode to base metal

(NOTE: Welding leads must connect to correct terminals if the machine has a polarity switch. Otherwise, a change in polarity is made by reversing leads on the terminals.)

XI. Factors that determine correct polarities to use

A. Electrode

B. Type of flux on electrode

(NOTE: Use *Electrode Guidebook* to determine correct polarity for different electrodes.)

EXAMPLES: E-6010 (+) reverse polarity
E-6012 AC-DCSP (−) straight polarity
E-7018 AC-DCRP (+) reverse polarity
E-7024 AC-DCRP-SP (−) reverse or straight polarity

INFORMATION SHEET

XII. Purposes of electrode flux

- A. Stabilizing arc
- B. Shielding molten puddle from air
- C. Floating impurities out of puddle
- D. Forming slag and slowing down cooling
- E. Increasing welding speed
- F. Improving quality of weld
- G. Adding alloying elements to weld metal

XIII. Factors to consider when selecting electrodes

- A. Plans and specifications
- B. Physical and chemical properties of base metal
- C. Composition of base metal
- D. Thickness and shape of base metal
- E. Welding position
- F. Welding current
- G. Joint design and fit-up
- H. Production efficiency and job conditions

XIV. Effects of raising and lowering welding machine amperes

- A. Raising amperes — Produces more heat; increases penetration
- B. Lowering amperes — Produces less heat; decreases penetration

INFORMATION SHEET

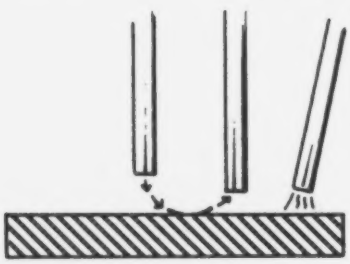
XV. Methods of striking an arc (Figures 1 and 2)

A. Scratching

(NOTE: The scratching method is similar to striking a match.)

EXAMPLE:

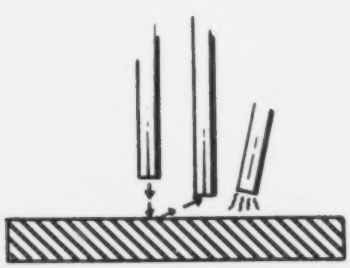
FIGURE 1



B. Tapping

EXAMPLE:

FIGURE 2



XVI. Characteristics of proper arc length

A. End of electrode same distance from base metal as diameter of electrode

EXAMPLE: When using 1/8-inch electrode, arc length should be 1/8 inch.

B. Arc length making steady hum at welder and frying sound at arc

XVII. Parts of the welding process (Transparency #4)

A. Electrode

INFORMATION SHEET

B. Wire core

C. Coating (flux)

D. Arc

E. Gaseous shield

F. Weld

G. Slag

H. Heat lines

I. Base metal

J. Penetration

K. Crater

L. Angle of electrode 15 to 30 degrees

M. Direction of travel

XVIII. Descriptions of types of welds

A. Bead weld — Weld made by one pass of electrode

B. Fillet weld — Weld made in corner or angle formed by two pieces of metal with welded surfaces at approximately 90-degree angles to each other

C. Groove weld — Weld made in groove formed by two beveled pieces of metal

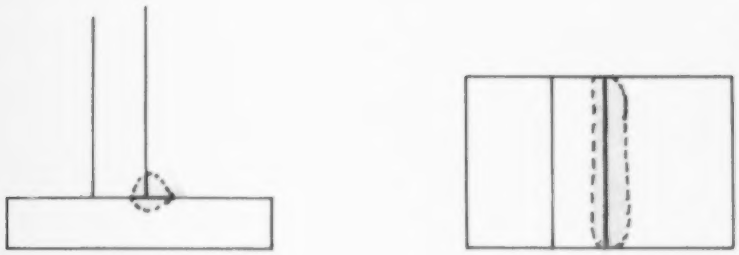
D. Tack weld — Temporary weld made to hold parts in alignment until final welds are made

INFORMATION SHEET

XIX. Types of welds (Figures 3-5)

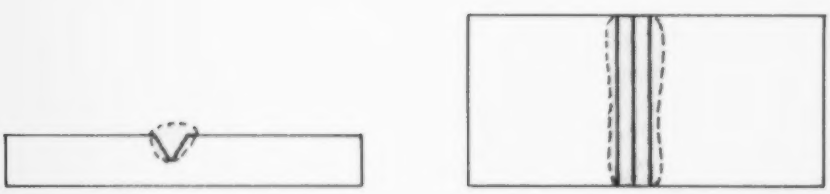
A. Fillet

FIGURE 3



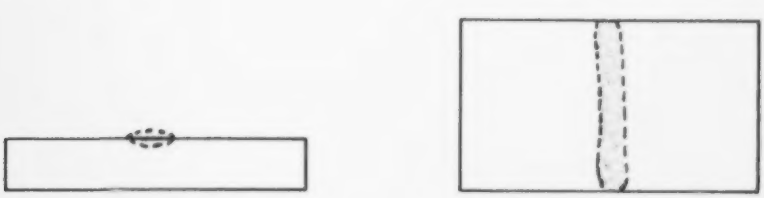
B. Groove

FIGURE 4



C. Bead

FIGURE 5

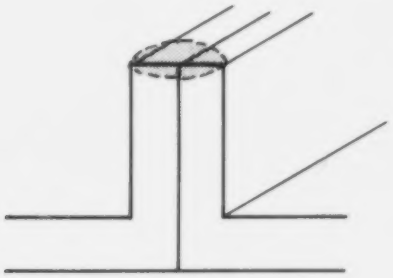


INFORMATION SHEET

XX. Types of weld joints (Figures 6-10)

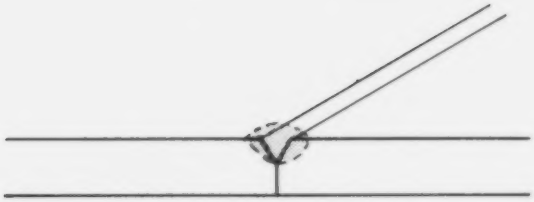
A. Edge

FIGURE 6



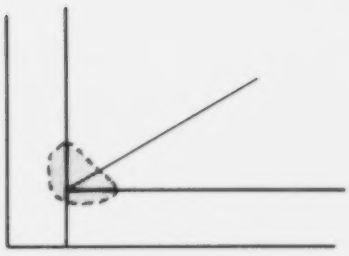
B. Butt

FIGURE 7



C. Corner

FIGURE 8

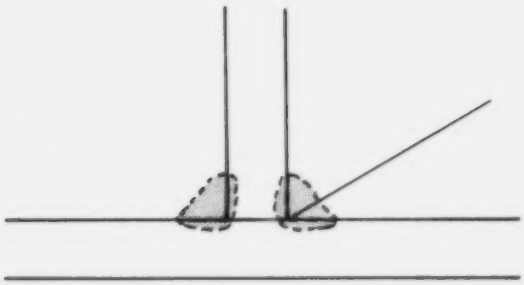


1930

INFORMATION SHEET

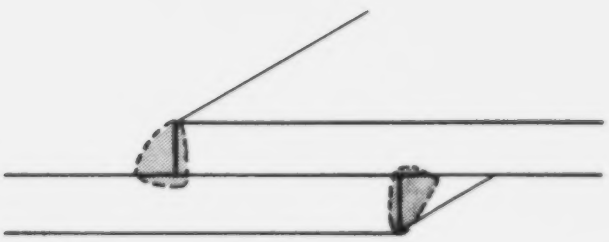
D. T

FIGURE 9



E. Lap

FIGURE 10

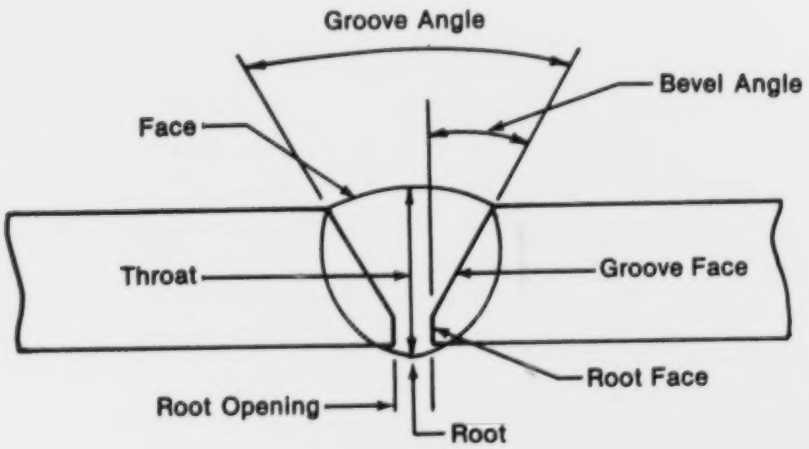


INFORMATION SHEET

XXI. Parts of groove and fillet welds (Figures 11 and 12)

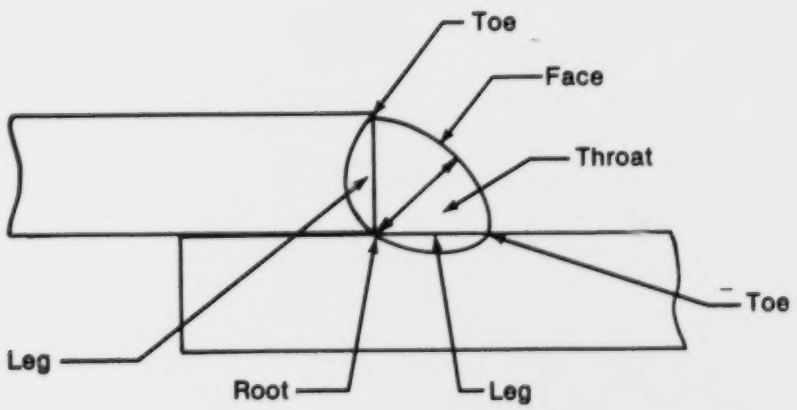
A. Groove

FIGURE 11



B. Fillet

FIGURE 12



INFORMATION SHEET

XXII. Positions used in arc welding (Transparency #5)

A. Flat

B. Horizontal

C. Vertical

(NOTE: In vertical position, the bead may be started either from top or bottom, depending on characteristics of metal and plans and specifications.)

D. Overhead

XXIII. Reasons for poor welds

A. Incorrect machine adjustment

B. Too large or too small electrode

C. Improper movement of electrode

(NOTE: You must consider rate of travel and pattern of movement of the electrode.)

D. Improper angle of electrode

E. Improper preparation of base metal

F. Incorrect arc length

XXIV. Types of electrode motions (rod manipulations) (See Figures 13-15.)

(NOTE: On a single-layer weld, to ensure proper fusion in the root zone, the arc may progress with a straight, forward motion or an oscillating motion, depending on size of joint to be filled.)

A. Small oscillating motion

B. Small circular motion

C. Back-and-forth motion with half circle

D. Figure-eight motion

INFORMATION SHEET

E. Triangular motion

(NOTE: Most operators use all of these motions, depending upon type of seam, type of joint, size of weld, and position of weld.)

EXAMPLES:

FIGURE 13

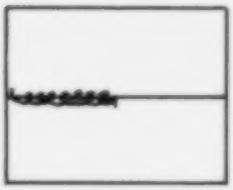


FIGURE 14

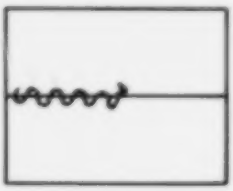
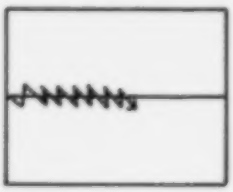


FIGURE 15



XXV. Characteristics of a good weld (Transparency #6)

A. Smooth edges

B. Correct bead size

C. Even penetration (well fused)

D. Even ripple

E. Clean, bright weld

F. Slight crown

XXVI. Elements of welding symbols and their descriptions (Transparencies #7 and #8)

(NOTE: The term *weld symbol* indicates the type of weld. The term *welding symbol* includes type of weld and other information.)

A. Reference line

1. Top — Contains information for weld on side opposite arrow
2. Bottom — Contains information for weld on arrow side

B. Arrow — Points toward joint

C. Basic weld symbols — Indicate type of weld

D. Dimensions and other data — Indicate size, length of weld; shown on same side of reference line as weld symbol

INFORMATION SHEET

E. Supplementary symbols — Indicate contour, backing or spacer material, melt-through, field weld, weld all around

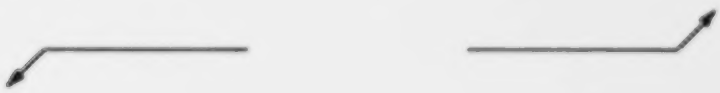
F. Finish symbols — Indicate method of finish

G. Tail — Includes specification, process, or other reference (Figure 16)

(NOTE: The welding symbol does not have a tail if there is not a specification, process, or other reference.)

EXAMPLES:

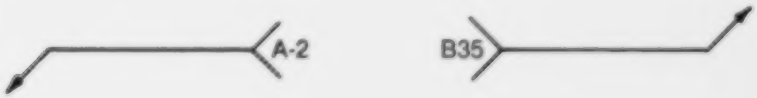
FIGURE 16



H. Specification, process, or other reference — Details information pertinent to weld; shown inside tail (Figure 17)

EXAMPLES:

FIGURE 17



XXVII. Symbols showing location of weld (Figures 18-20; Transparencies #9-#32)

A. Weld on arrow side of joint — Shown by placing weld symbol beneath reference line

EXAMPLES:

FIGURE 18

INFORMATION SHEET

B. Weld on other side of joint — Shown by placing weld symbol on top of reference line

EXAMPLES:

FIGURE 19

C. Weld on both sides of joint — Shown by placing weld symbols on both sides of reference line

EXAMPLES:

FIGURE 20

XXVIII. Basic weld symbols (Figure 21)

FIGURE 21

Groove							
Square	Scarf*	V	Bevel	U	J	Flared V	Flared Bevel

Fillet	Plug or Slot	Spot or Projection	Seam	Back or Backing	Surfacing	Flange	
						Edge	Corner

*Used for brazed joints only

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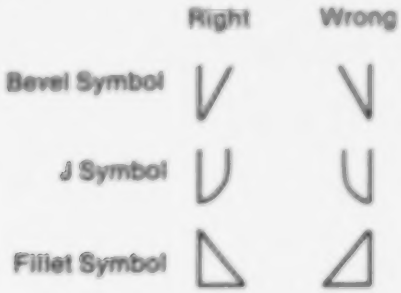
INFORMATION SHEET

XXIX. Correct and incorrect drawing of symbols with one vertical side

(NOTE: Draw symbols that have one vertical side with that side always on the left. See Figure 22.)

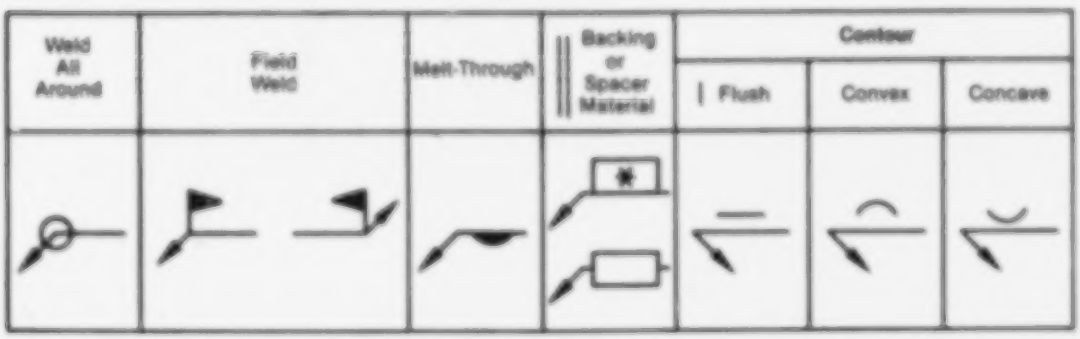
EXAMPLES: Fillet, bevel and J-groove, flared bevel-groove, and corner-flange weld symbols

FIGURE 22



XXX. Supplementary symbols (Figure 23)

FIGURE 23



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INFORMATION SHEET

XXXI. Finish symbols used with contour symbols (Figures 24-28)

(NOTE: Finishing of welds, other than cleaning, is indicated by appropriate contour and finish symbols. These symbols indicate the method, not the degree, of finish.)

A. M — Machined

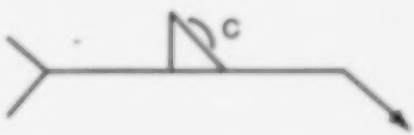
EXAMPLE:

FIGURE 24

B. C — Chipped

EXAMPLE:

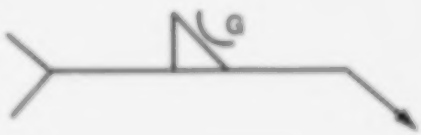
FIGURE 25



C. G — Ground

EXAMPLE:

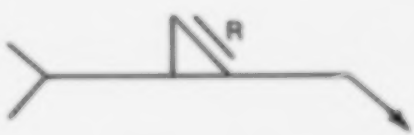
FIGURE 26



D. R — Rolled

EXAMPLE:

FIGURE 27

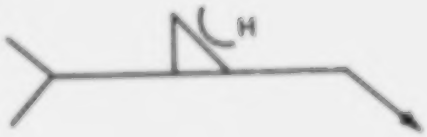


INFORMATION SHEET

E. H — Hammered

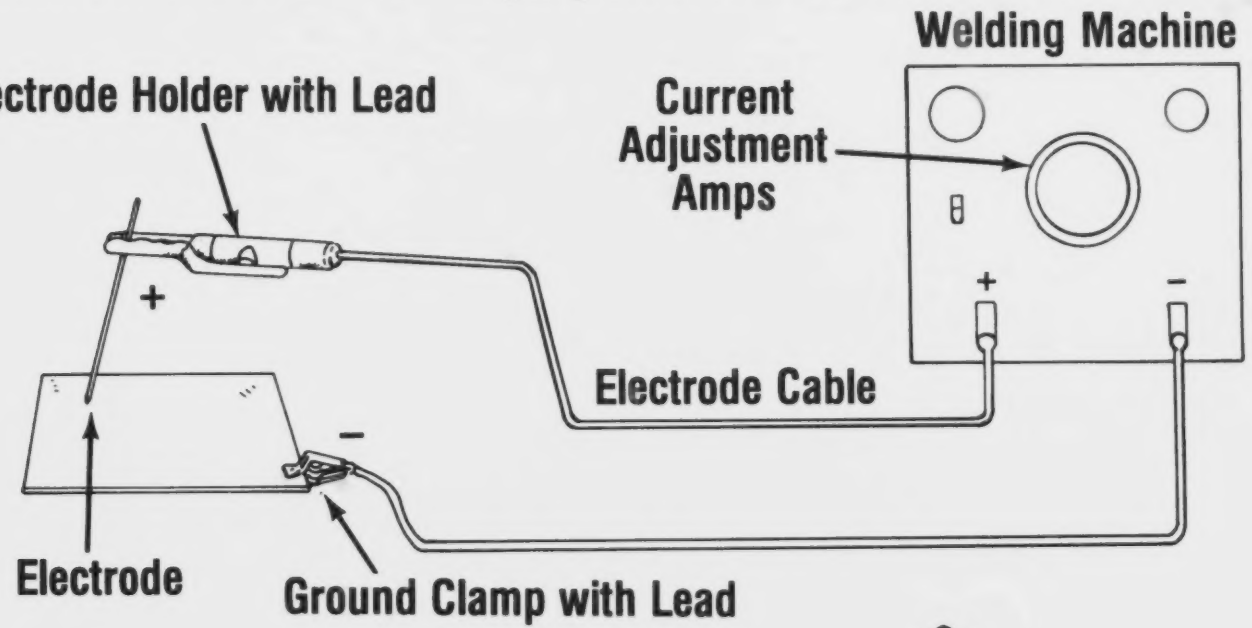
EXAMPLE:

FIGURE 28



1939

Common Tools and Equipment Used in Arc Welding

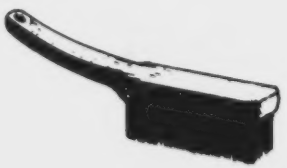


Shield or Helmet

Welding Goggles

Chipping Hammer

Leather Gloves



Wire Brush

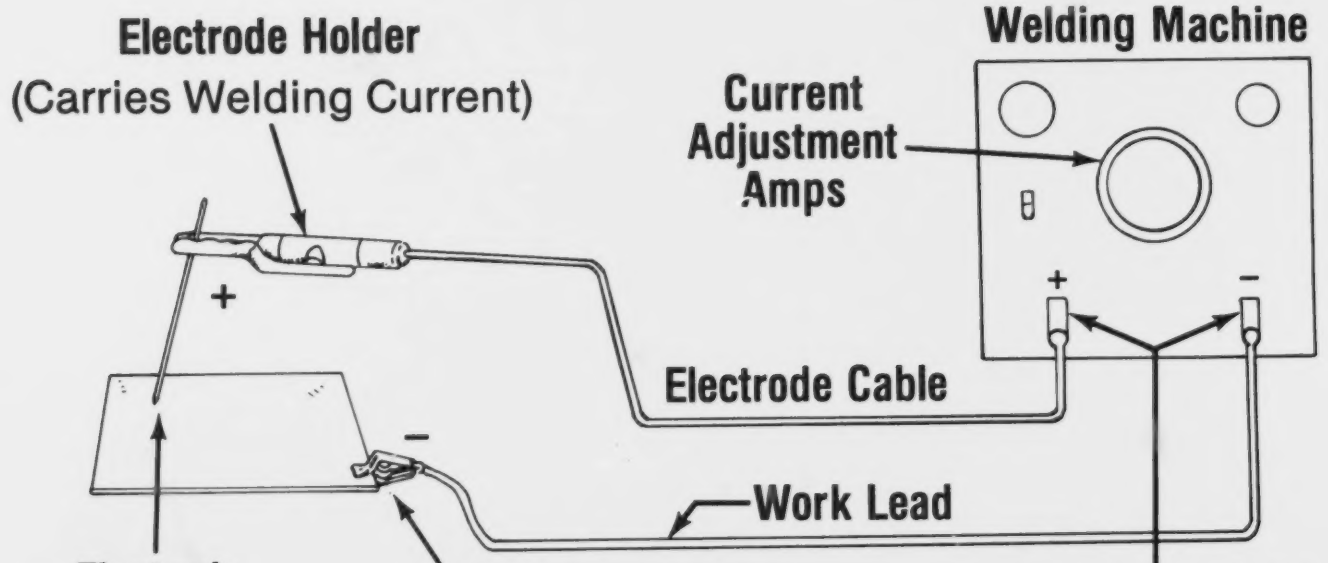
1940

1941

TM #1

HEM - 27-G

Welding Circuit



Reverse:

1. Electrode (+)
2. Current flows from base metal to electrode
3. Two-thirds heat at (+) electrode; one-third heat at (−) work

Straight:

1. Electrode (−)
2. Current flows from electrode to base metal
3. Two-thirds heat at (−) work; one-third heat at (+) electrode

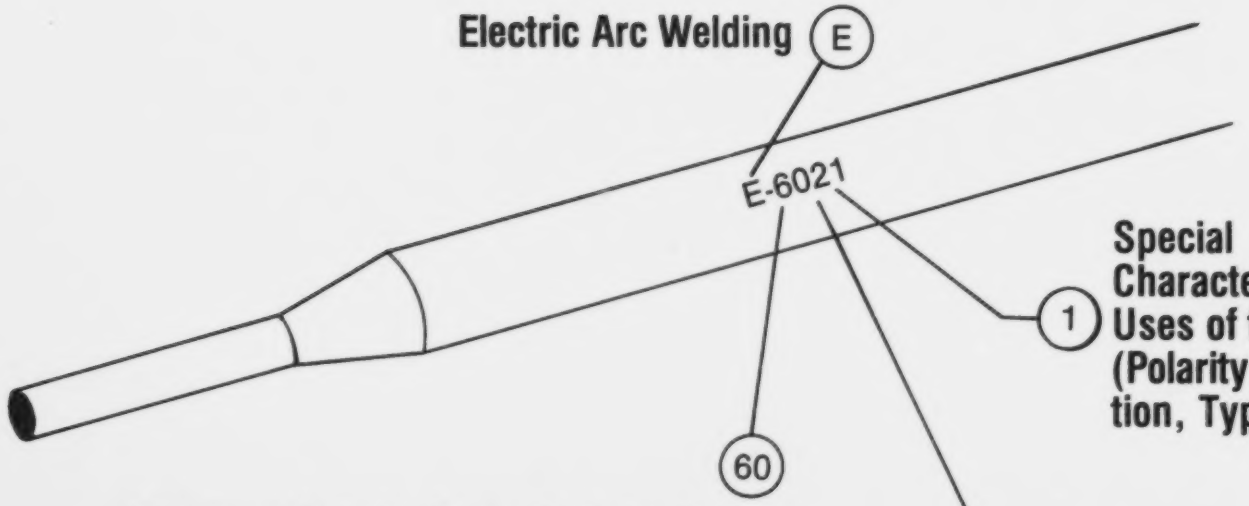
TM #2

1942

1942

HEM - 29-G

AWS Electrode Classification System


Electric Arc Welding
E
E-6021
1
Special Characteristics and Uses of the Electrode (Polarity, Penetration, Type of Welder)
60
Minimum Tensile Strength Deposited in Thousands of Pounds per Square Inch
2
WeldingPosition (1--Indicates All Positions, 2--Indicates Flat and Horizontal Only, 3--Indicates Flat Only)

E-6021 Mild-Steel Electrode

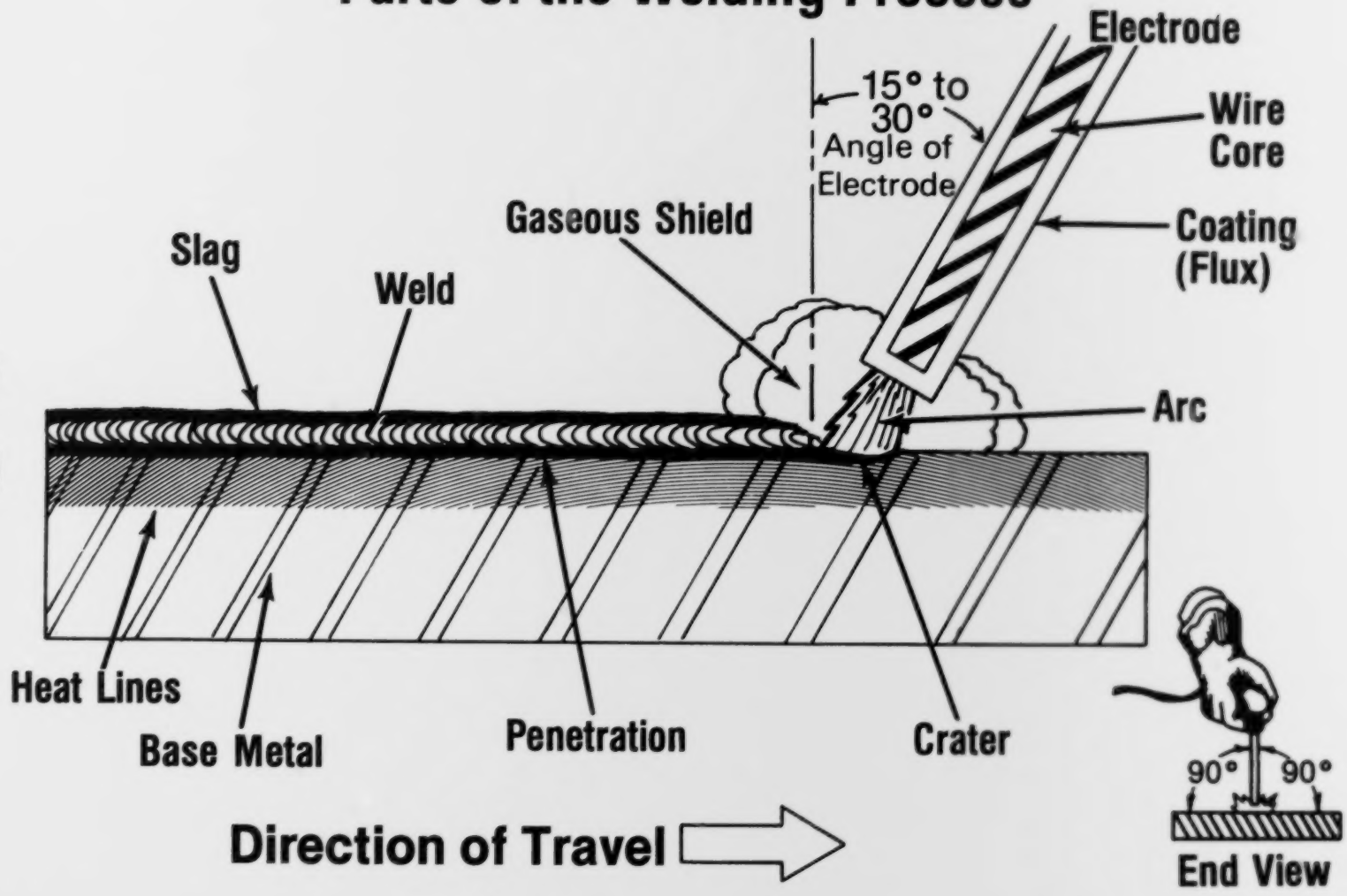
TM #3

1944

1945

HEM - 31-G

Parts of the Welding Process



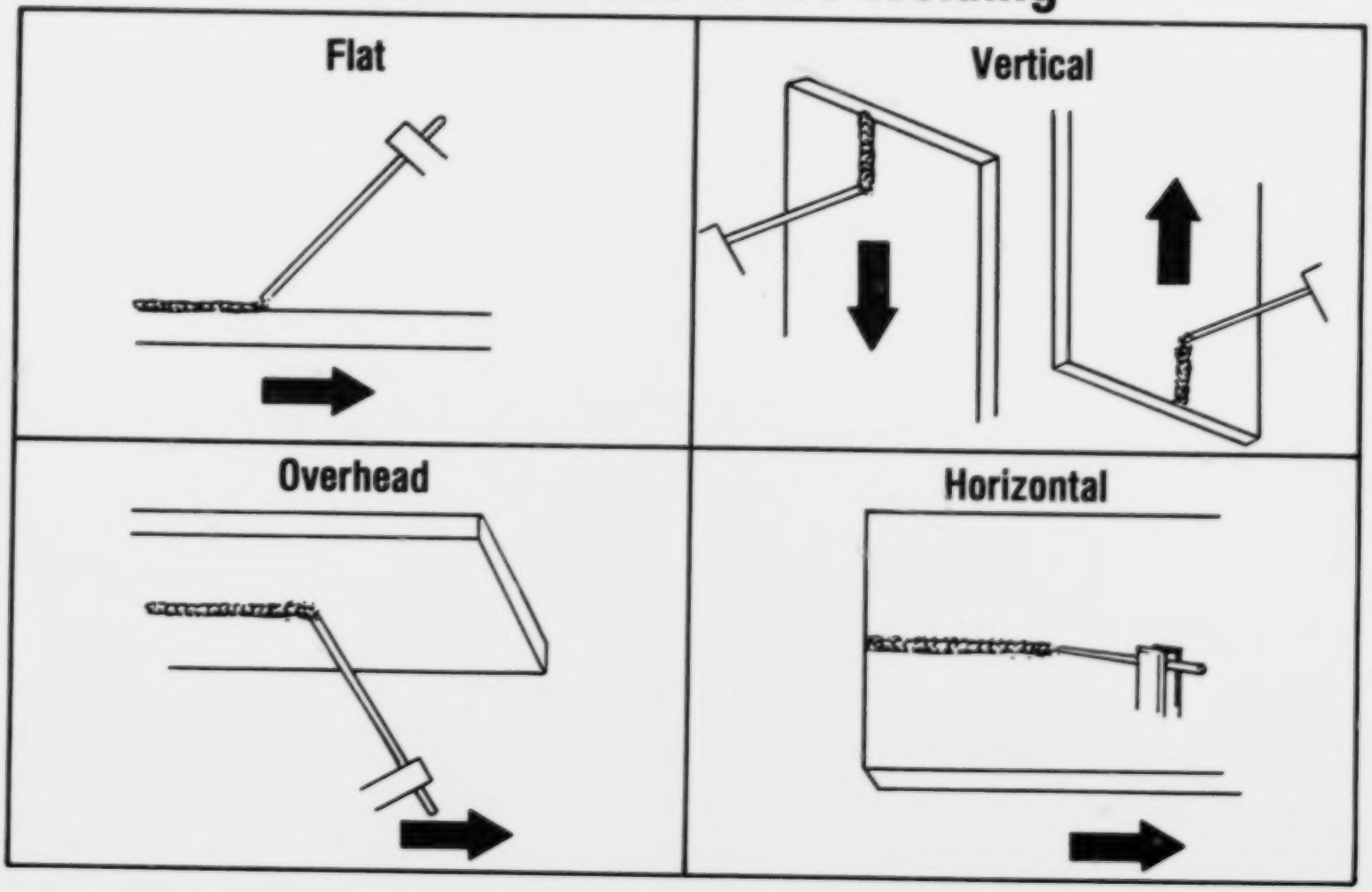
TM #4

1946

1947

HEM - 33-G

Positions Used in Arc Welding



TM #5

1948

1949

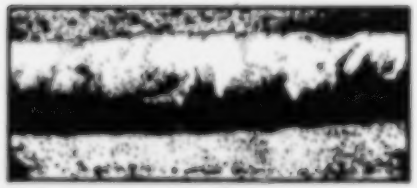
HEM - 35-G

Characteristics of a Good Weld

End View

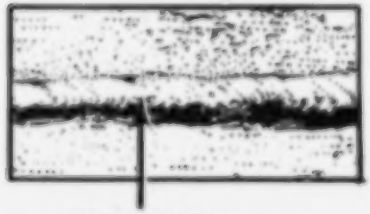
Even Penetration (Well-Fused)

Top View



Even Ripple

Bottom View



Slight Crown

End View

Correct Bead Size

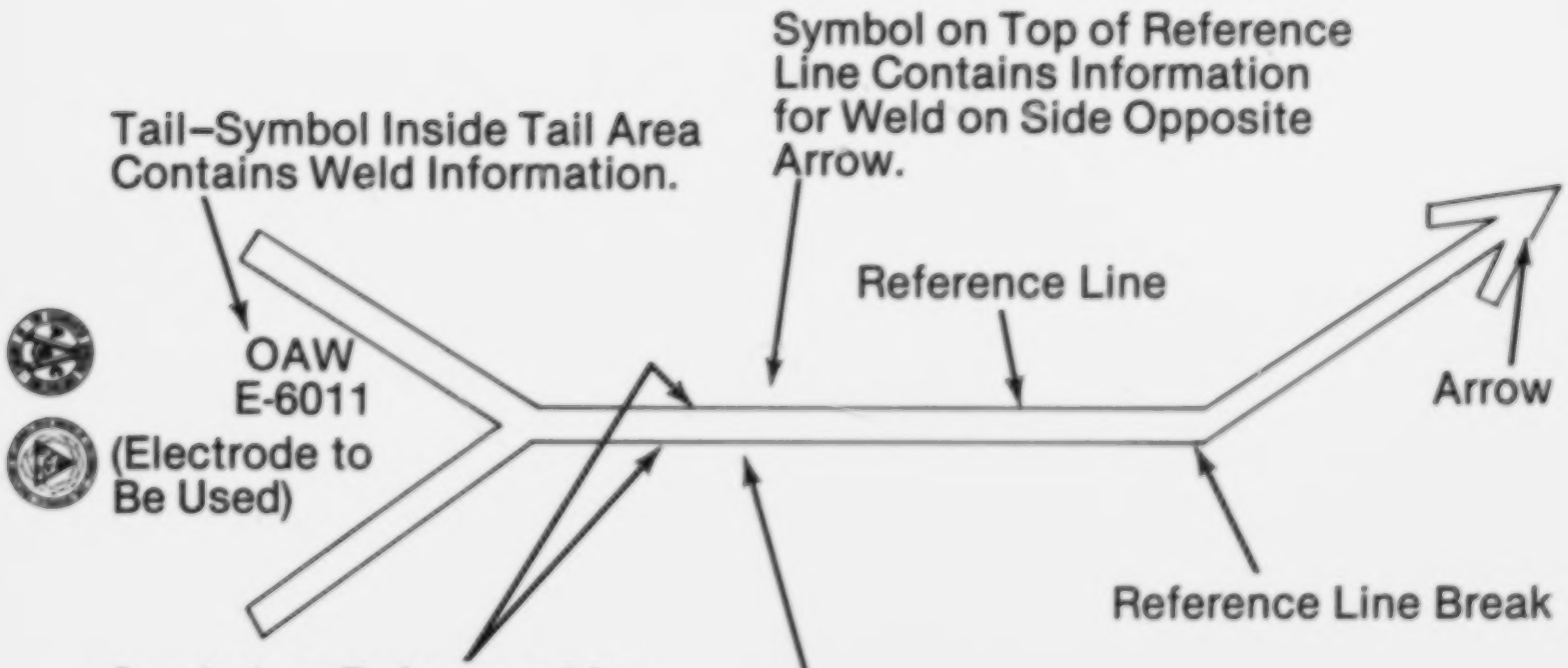
1950

1951

TM #6

HEM - 37-G

Elements of Welding Symbol


Tail–Symbol Inside Tail Area Contains Weld Information.
Symbol on Top of Reference Line Contains Information for Weld on Side Opposite Arrow.
Reference Line
Arrow
OAW
E-6011
(Electrode to Be Used)
Reference Line Break
Symbol on Reference Line Contains Information for Weld on Both Sides of Joint.
Symbol on Bottom of Reference Line Contains Information for Weld on Arrow Side of Joint.

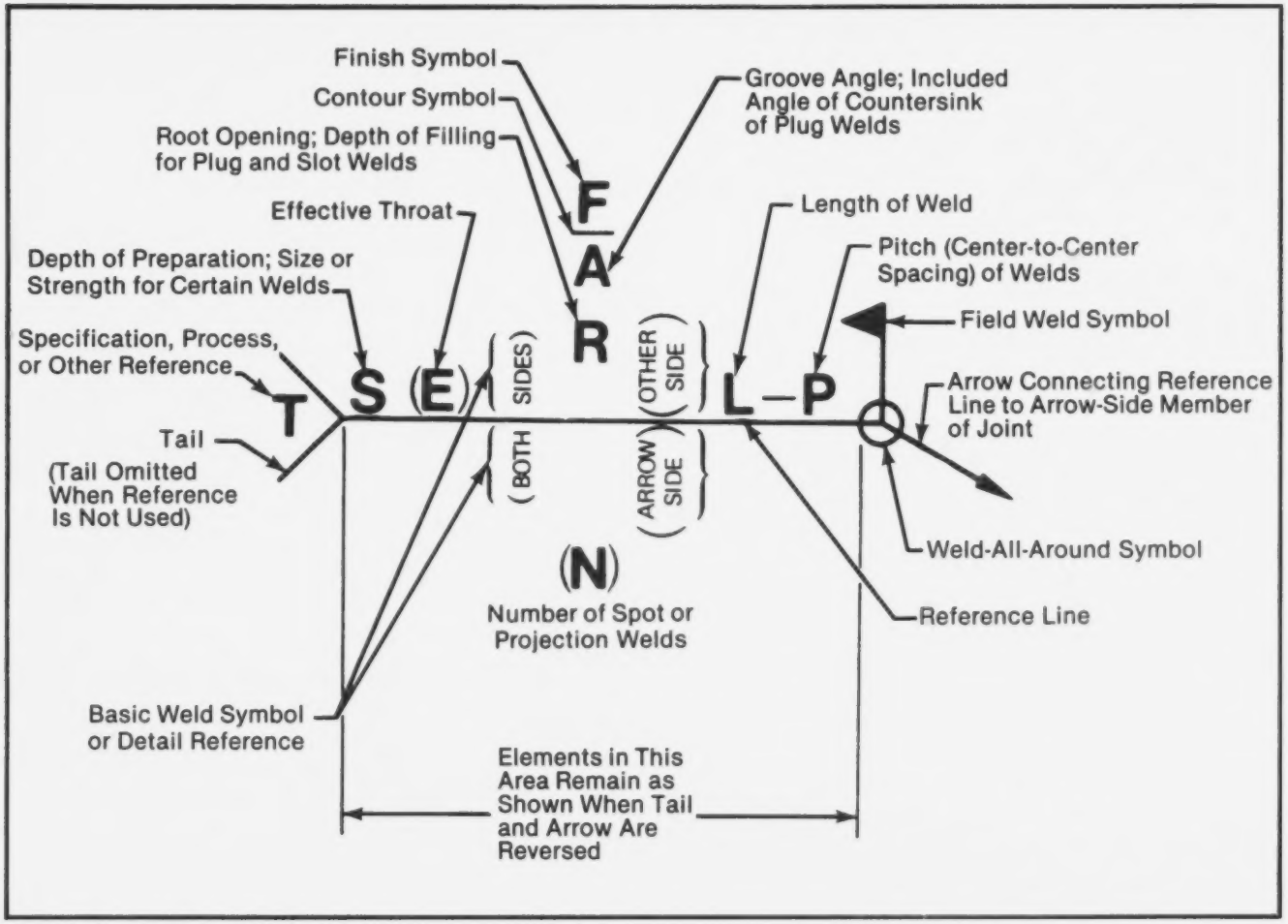
TM #7

1952

1953

HEM - 39-G

Standard Location of Welding Symbol Elements



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TM #8

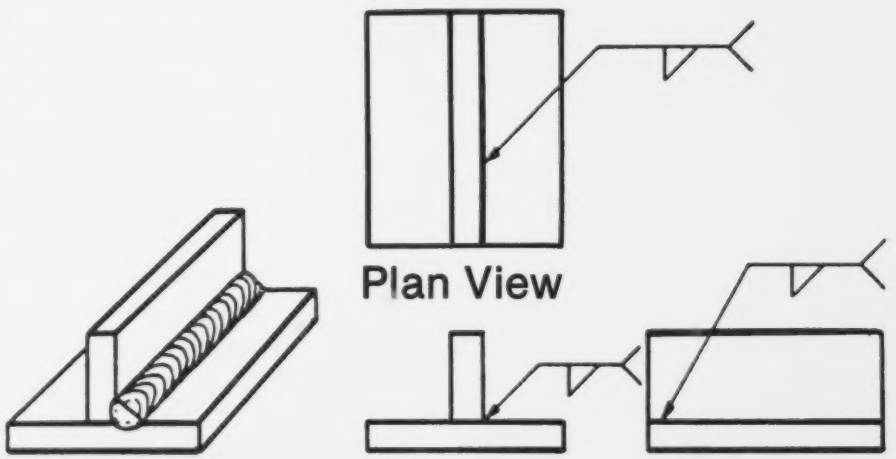
1954

1955

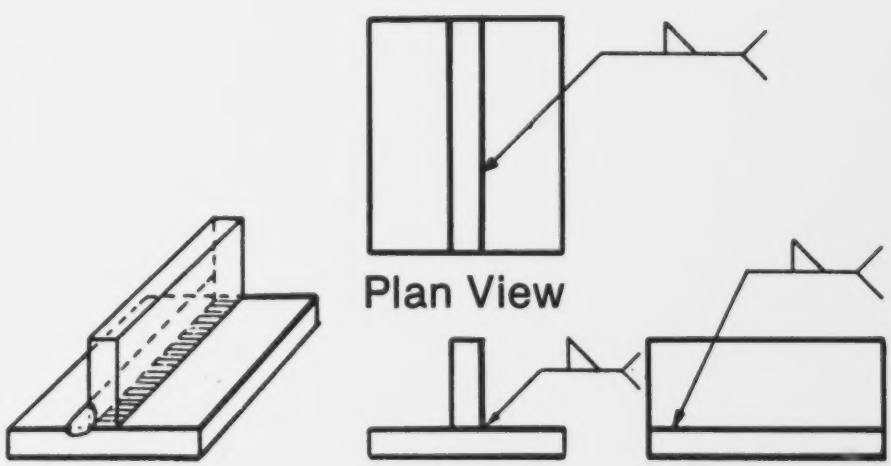
HEM - 41-G

Application of Fillet Welding Symbol

Arrow Side of Fillet Welding Symbol

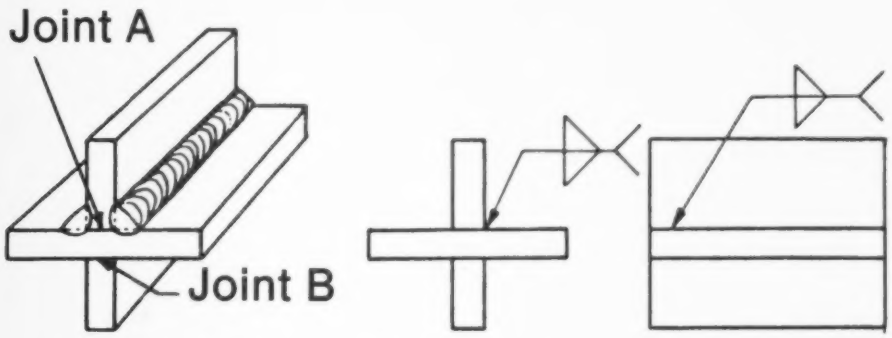


Other Side of Fillet Welding Symbol



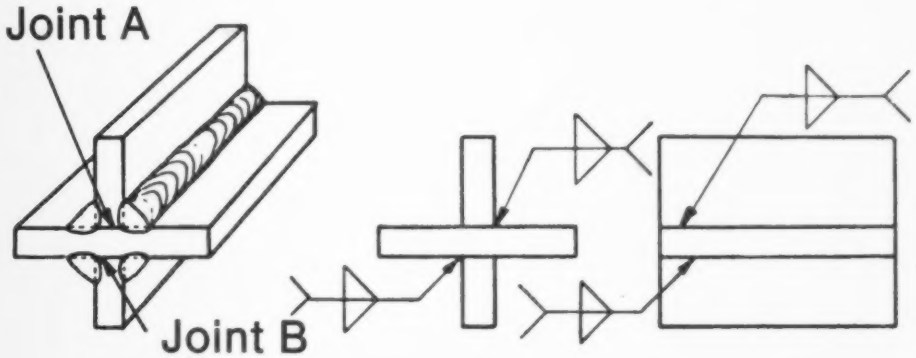
Application of Fillet Welding Symbol
(Continued)

Both Sides of Fillet Welding Symbol for One Joint



Desired Weld | Section or End View | Elevation

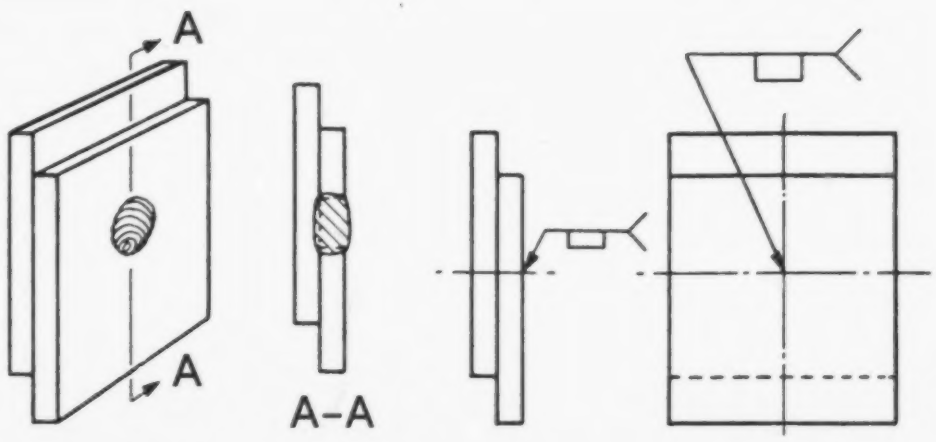
Both Sides of Fillet Welding Symbol for Two Joints



Desired Weld | Section or End View | Elevation

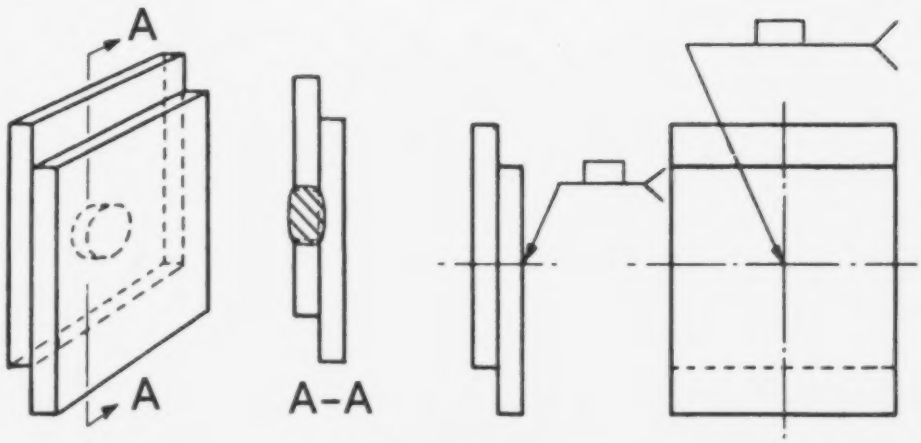
Application of Plug Welding Symbol

Arrow Side of Plug Welding Symbol



Desired Weld | Section or End View | Elevation

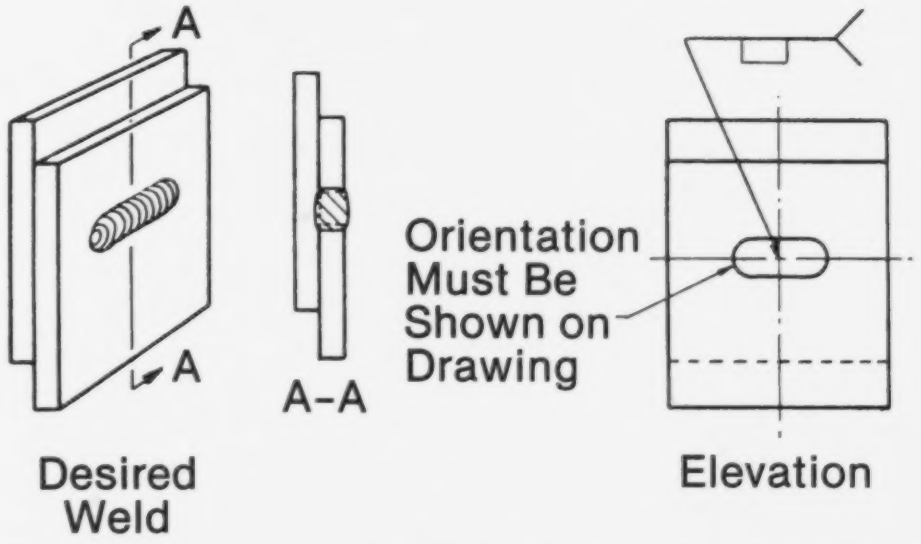
Other Side of Plug Welding Symbol



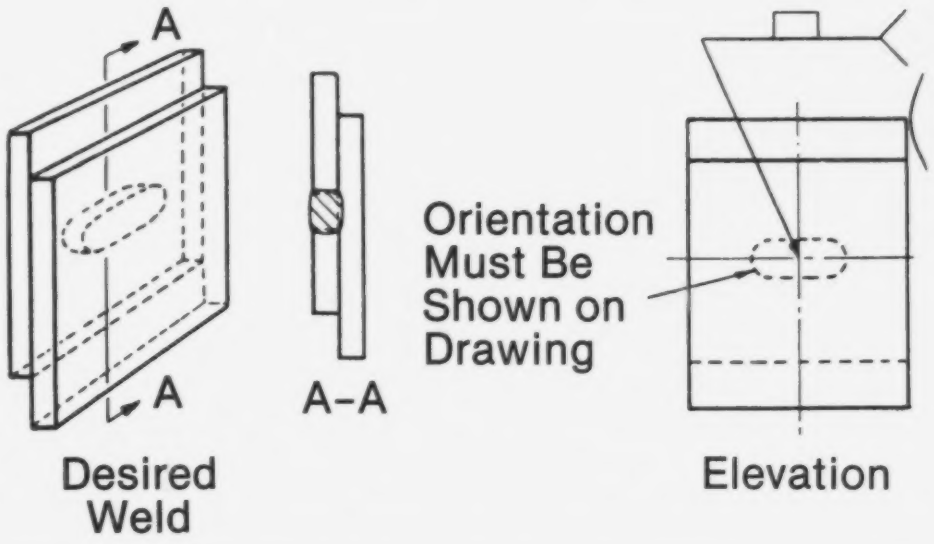
Desired Weld | Section or End View | Elevation

Application of Slot Welding Symbol

Arrow Side of Slot Welding Symbol



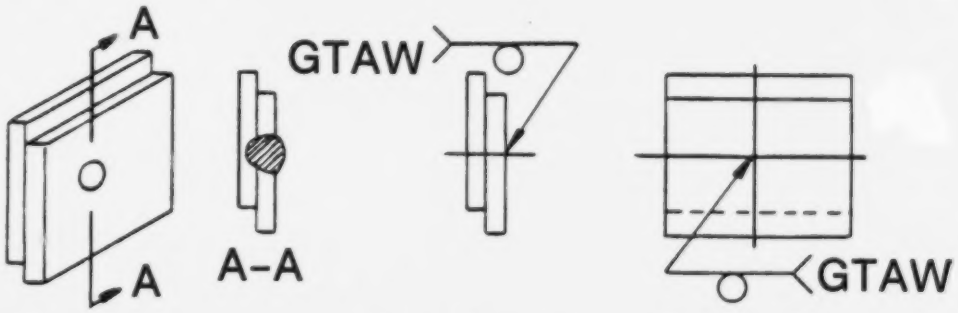
Other Side of Slot Welding Symbol



Application of Spot Welding Symbol

Arrow Side of Spot Welding Symbol

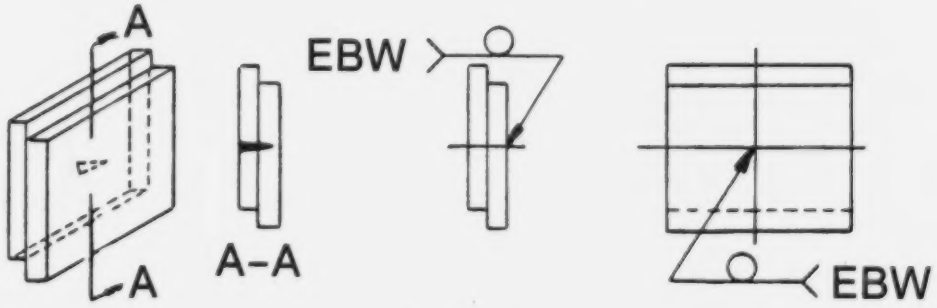
(Gas Tungsten-Arc Spot)



Desired Weld | Section or End View | Elevation

Other Side of Spot Welding Symbol

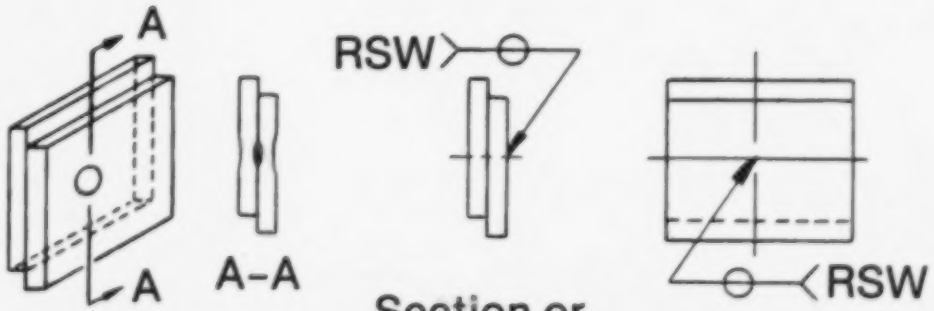
(Electron Beam Spot)



Desired Weld | Section or End View | Elevation

Application of Spot Welding Symbol
(Continued)

No Arrow- or Other-Side Reference or Significance
(Resistance Spot)



Desired Weld

Section or End View

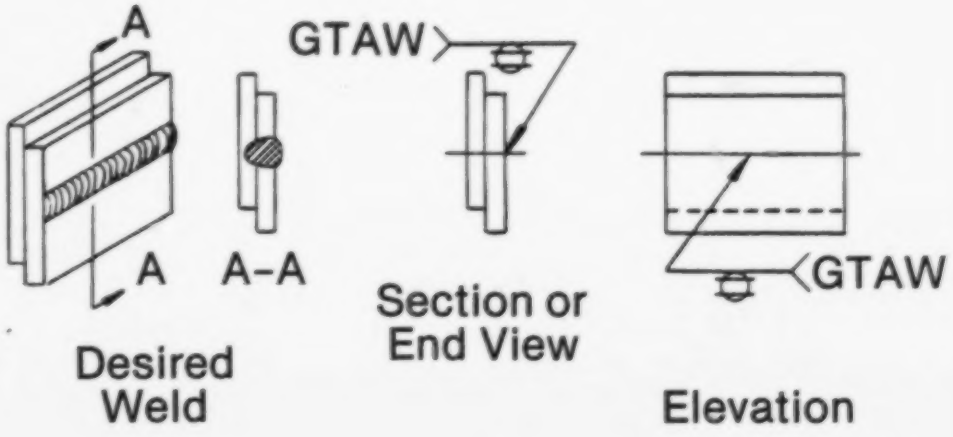
Elevation

1961

Application of Seam Welding Symbol

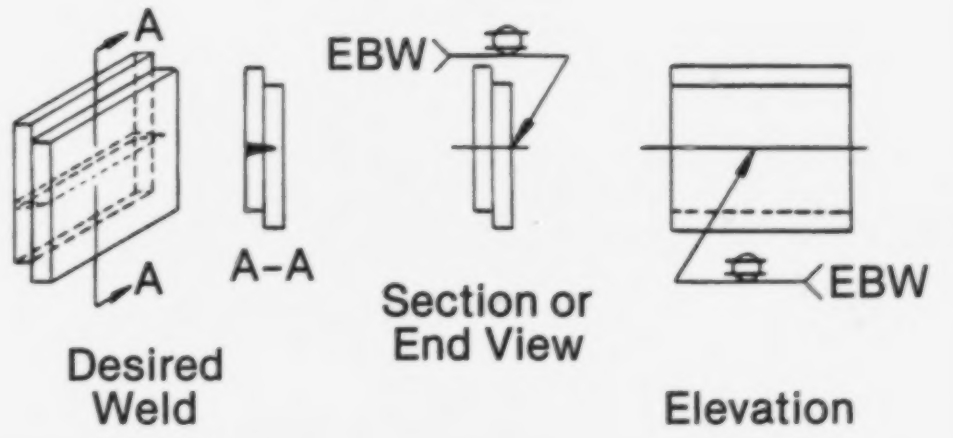
Arrow Side of Seam Welding Symbol

(Gas Tungsten-Arc Spot)



Other Side of Side Seam Welding Symbol

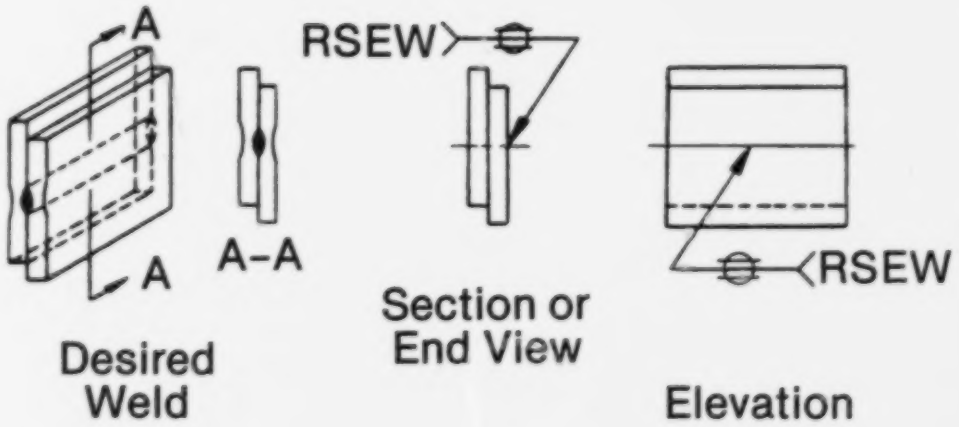
(Electron Beam Spot)



Application of Seam Welding Symbol
(Continued)

No Arrow- or Other-Side Reference or Significance

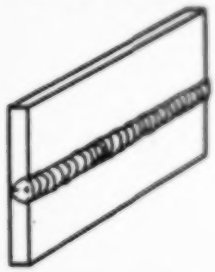
(Resistance Spot)



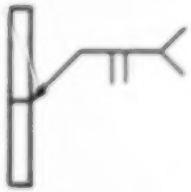
1963

Application of Square-Groove Welding Symbol

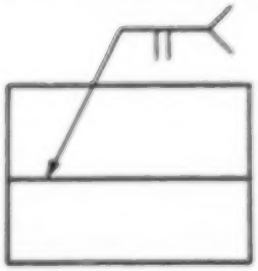
Arrow Side of Square-Groove Welding Symbol



Desired Weld

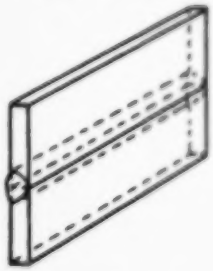


Section or End View

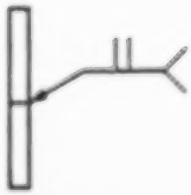


Elevation

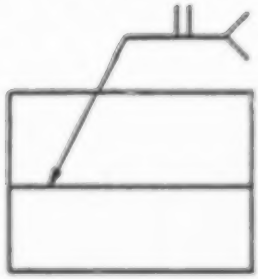
Other Side of Square-Groove Welding Symbol



Desired Weld

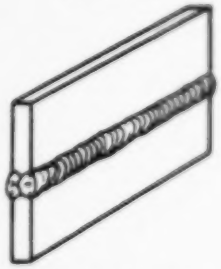


Section or End View

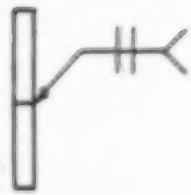


Elevation

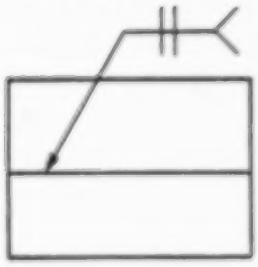
Both Sides of Square-Groove Welding Symbol



Desired Weld



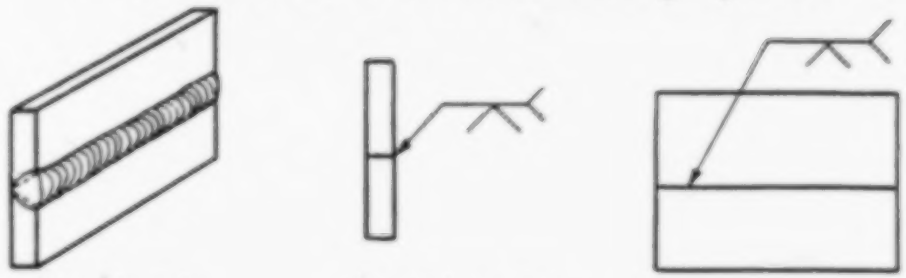
Section or End View



Elevation

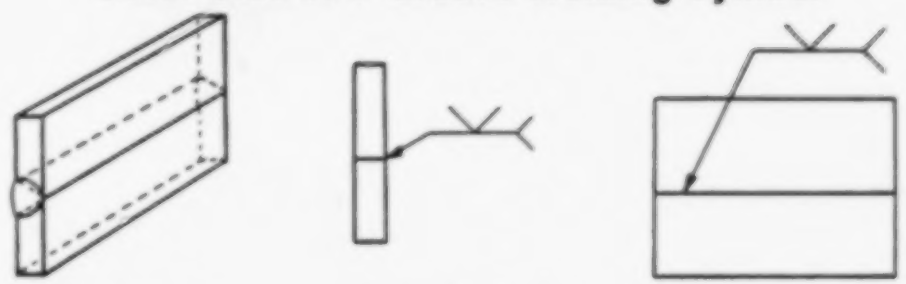
Application of V-Groove Welding Symbol

Arrow Side of V-Groove Welding Symbol



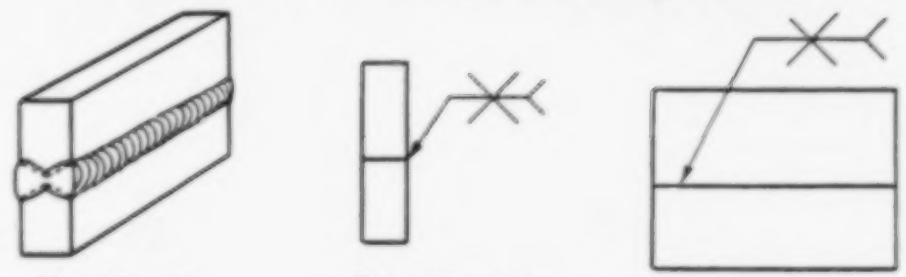
Desired Weld | Section or End View | Elevation

Other Side of V-Groove Welding Symbol



Desired Weld | Section or End View | Elevation

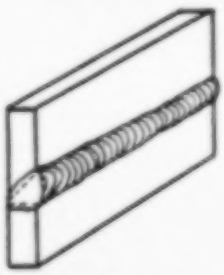
Both Sides of V-Groove Welding Symbol



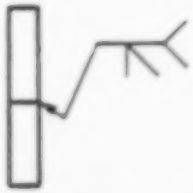
Desired Weld | Section or End View | Elevation

Application of Bevel-Groove Welding Symbol

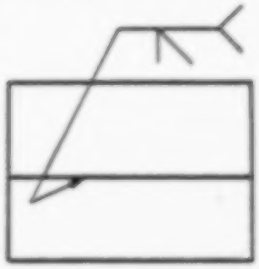
Arrow Side of Bevel-Groove Welding Symbol



Desired Weld

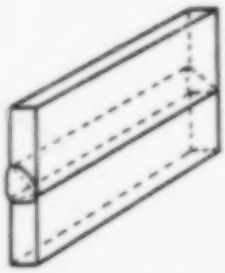


Section or End View



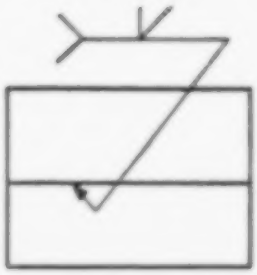
Elevation

Other Side of Bevel-Groove Welding Symbol



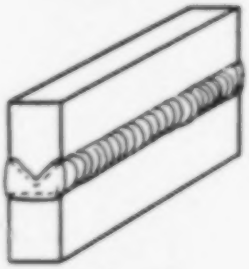
Desired Weld

Section or End View

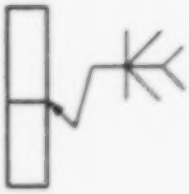


Elevation

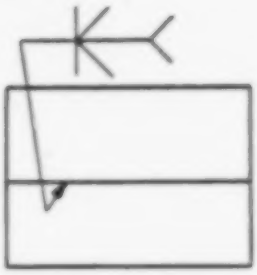
Both Sides of Bevel-Groove Welding Symbol



Desired Weld



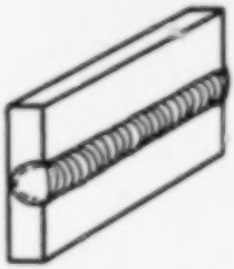
Section or End View



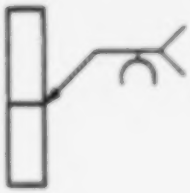
Elevation

Application of U-Groove Welding Symbol

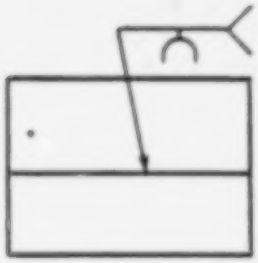
Arrow Side of U-Groove Welding Symbol



Desired Weld

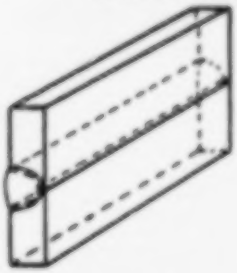


Section or End View



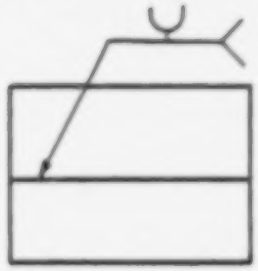
Elevation

Other Side of U-Groove Welding Symbol



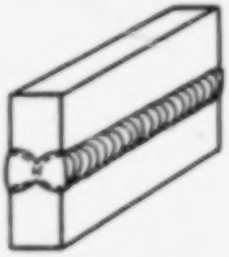
Desired Weld

Section or End View

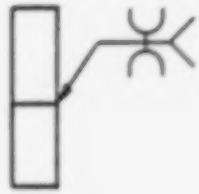


Elevation

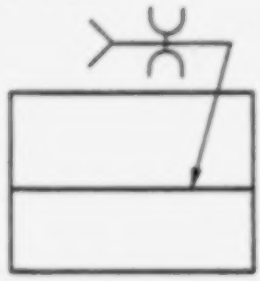
Both Sides of U-Groove Welding Symbol



Desired Weld



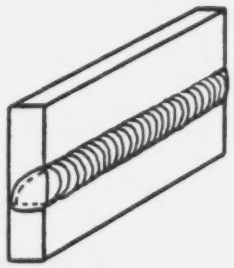
Section or End View



Elevation

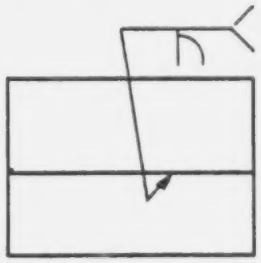
Application of J-Groove Welding Symbol

Arrow Side of J-Groove Welding Symbol



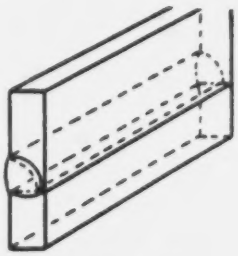
Desired Weld

Section or End View

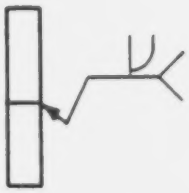


Elevation

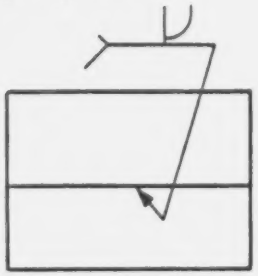
Other Side of J-Groove Welding Symbol



Desired Weld

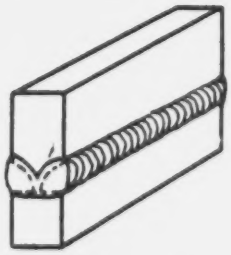


Section or End View

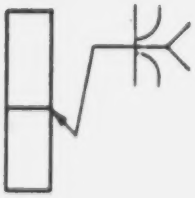


Elevation

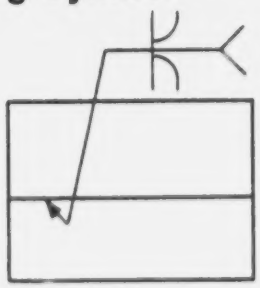
Both Sides of J-Groove Welding Symbol



Desired Weld



Section or End View

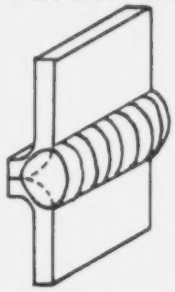


Elevation

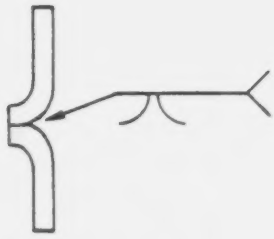
1968

Application of Flared V-Groove Welding Symbol

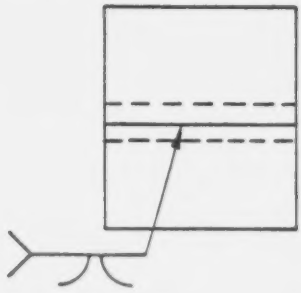
Arrow Side of Flared V-Groove Welding Symbol



Desired Weld

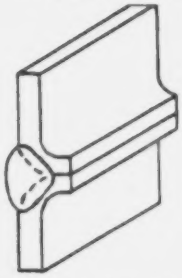


Section or End View

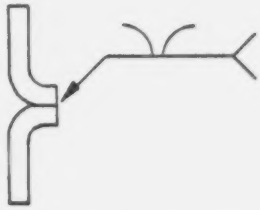


Elevation

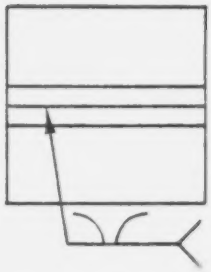
Other Side of Flared V-Groove Welding Symbol



Desired Weld

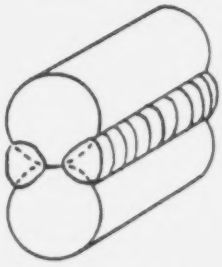


Section or End View

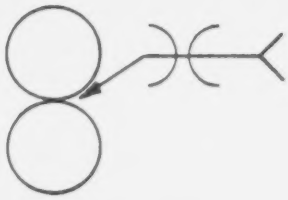


Elevation

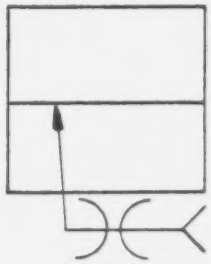
Both Sides of Flared V-Groove Welding Symbol



Desired Weld



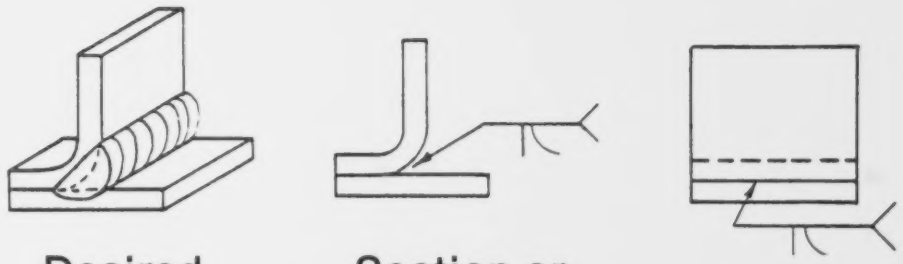
Section or End View



Elevation

Application of Flared Bevel-Groove Welding Symbol

Arrow Side of Flared Bevel-Groove Welding Symbol

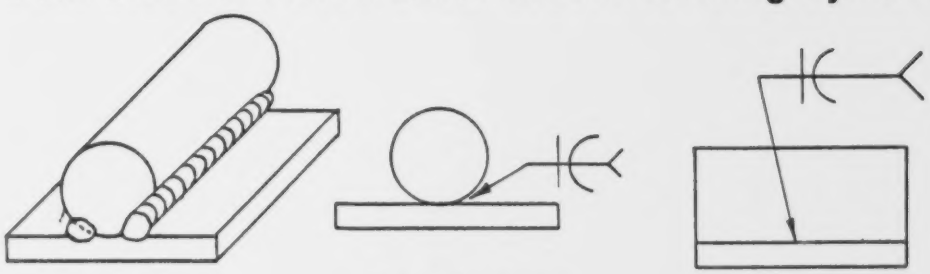


Desired Weld | Section or End View | Elevation

Other Side of Flared Bevel-Groove Welding Symbol

Desired Weld | Section or End View | Elevation

Both Sides of Flared Bevel-Groove Welding Symbol

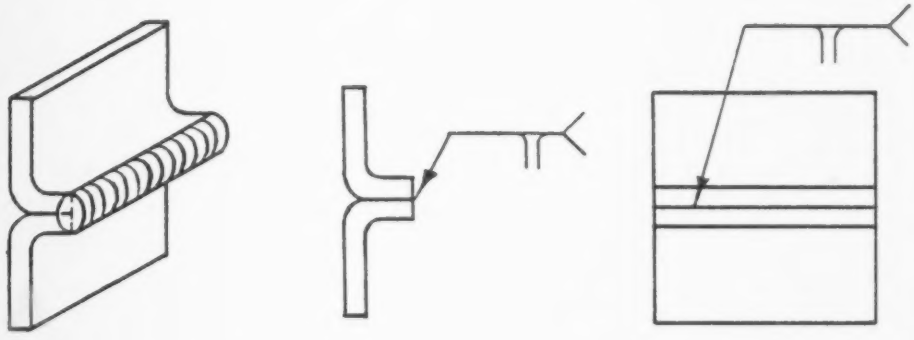


Desired Weld | Section or End View | Elevation

1970

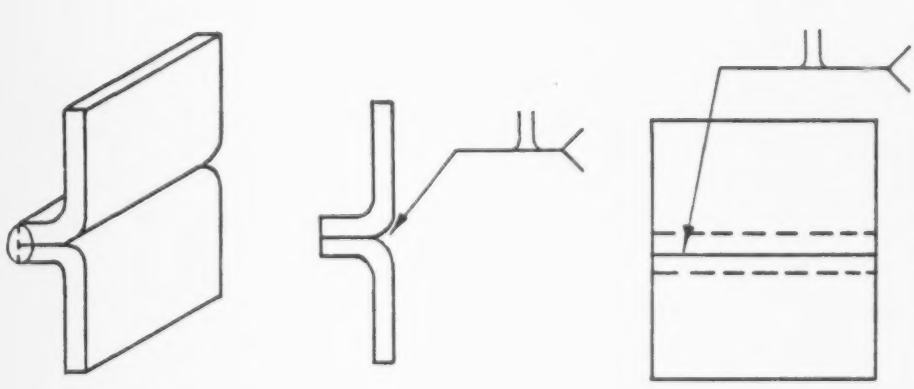
Application of Edge-Flange Welding Symbol

Arrow Side of Edge-Flange Welding Symbol



Desired Weld | Section or End View | Elevation

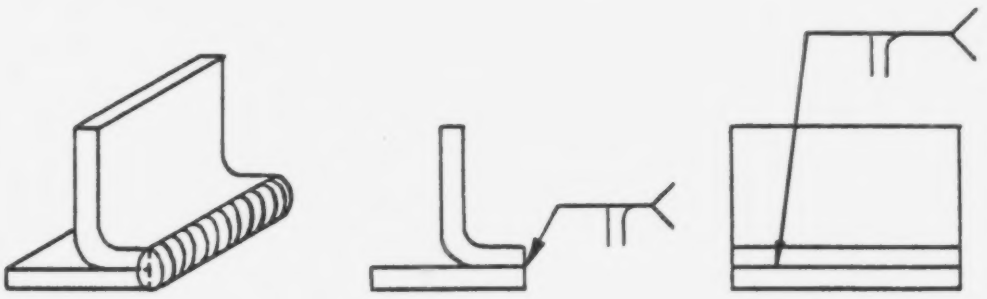
Other Side of Edge-Flange Welding Symbol



Desired Weld | Section or End View | Elevation

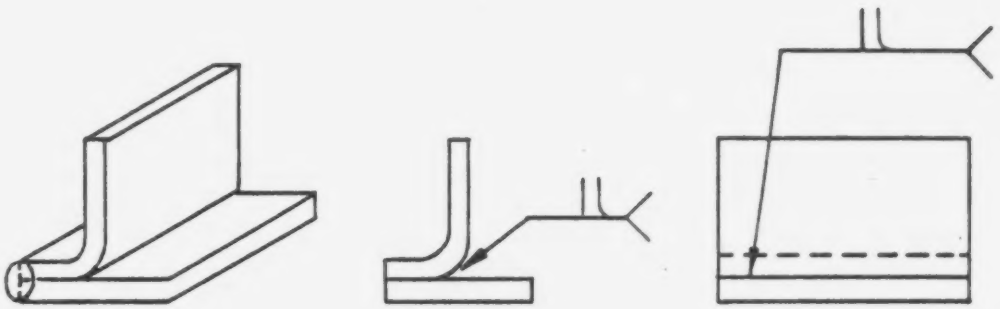
Application of Corner-Flange Welding Symbol

Arrow Side of Corner-Flange Welding Symbol



Desired Weld | Section or End View | Elevation

Other Side of Corner-Flange Welding Symbol

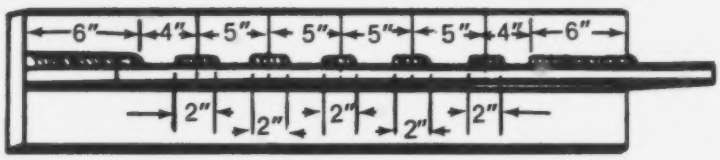


Desired Weld | Section or End View | Elevation

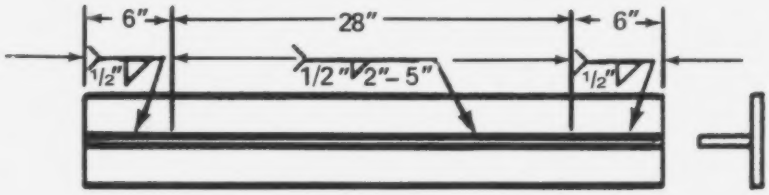
1972

Designation of Location and Extent of Fillet Welds

Combined Intermittent and Continuous Welding (One Side of Joint)

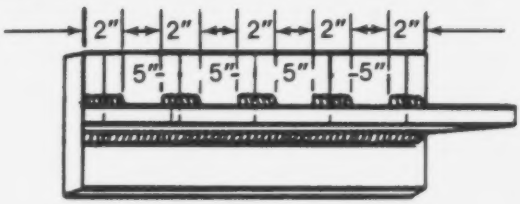


Desired Welds

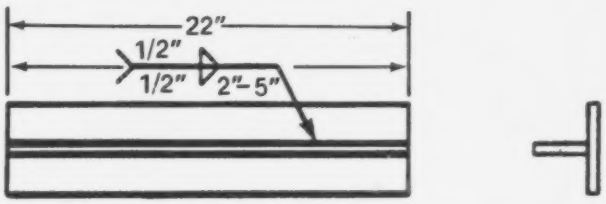


Symbols

Combined Intermittent and Continuous Welding (Opposite Sides of Joint)



Desired Welds



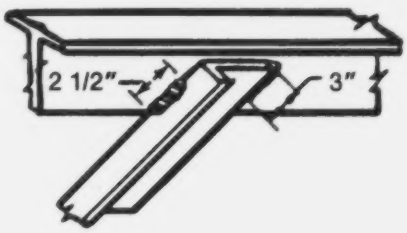
Symbols

1973

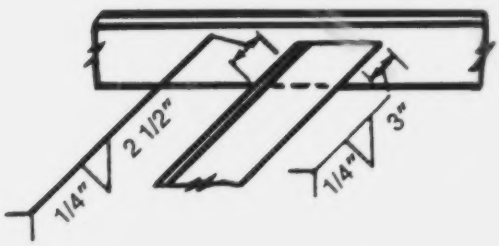
Designation of Location and Extent of Fillet Welds

(Continued)

Welds Definitely Located

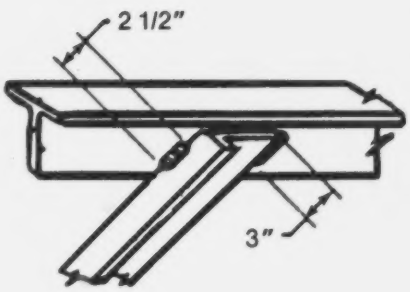


Desired Welds

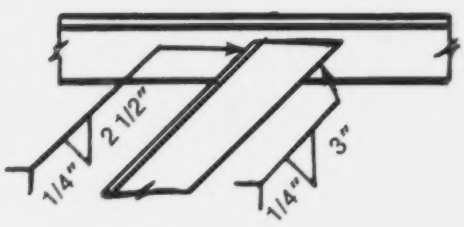


Symbols

Welds Approximately Located



Desired Welds

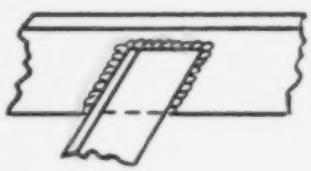
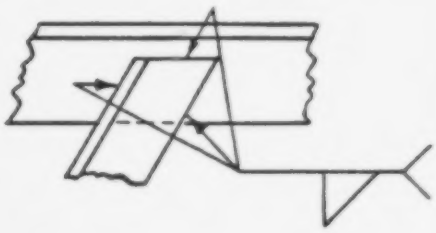
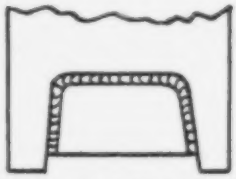
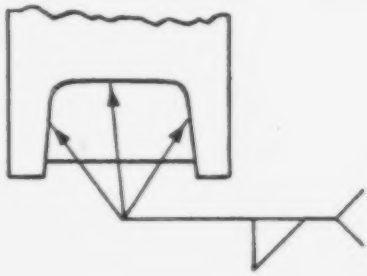
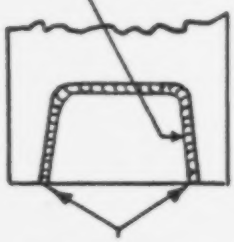
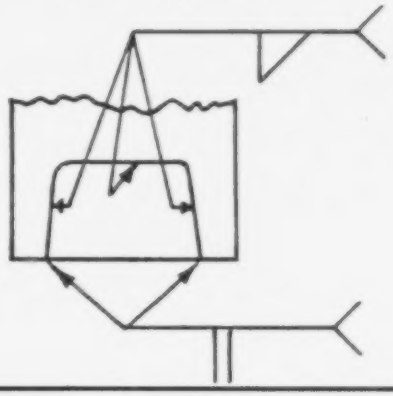


Symbols

(Welds May Be Placed Anywhere Along the Joint)

Designation of Extent of Welding

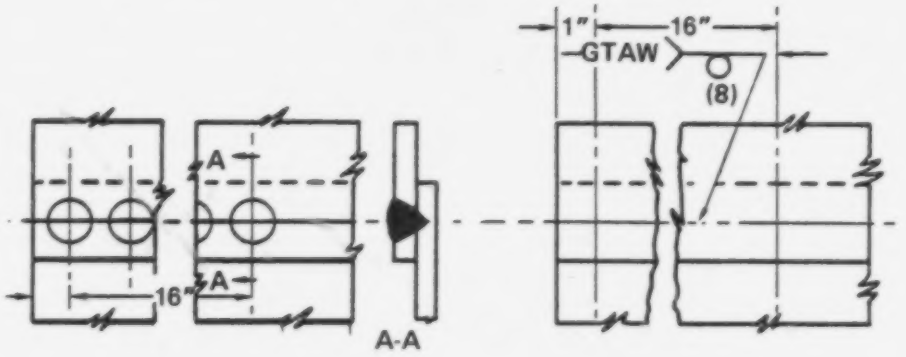
Weld with Abrupt Changes in Direction

Desired Weld:	Symbol
	
Desired Weld:	Symbol
 Fillet Weld on Three Sides; No Weld at Corners	
Desired Weld:	Symbol
Fillet Weld  Square-Groove Weld	

Application of Dimensions to Spot Welding Symbols

Desired Weld

Symbol

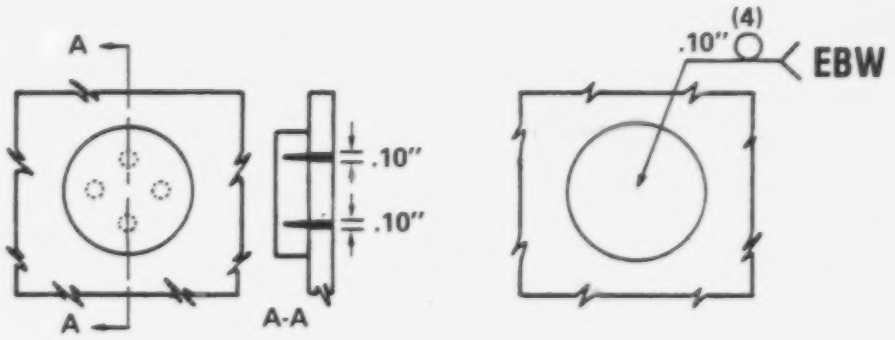


Extent of Spot Welding

(Gas Tungsten-Arc Spot)

Desired Welds

Symbol



Specified Number of Spot Welds Located at Random

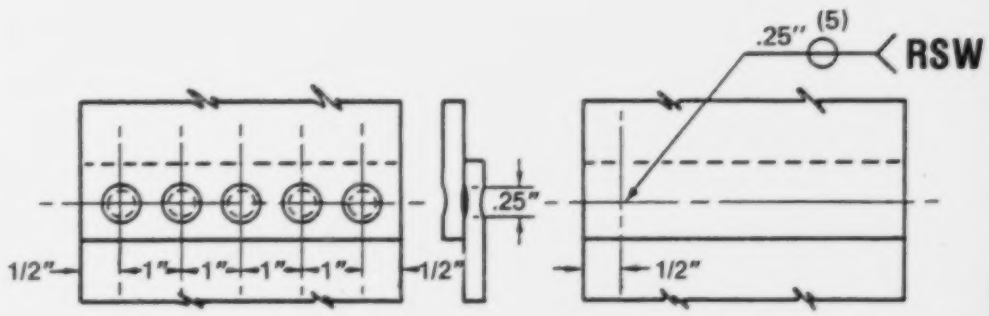
(Electron Beam Spot)

1976

Application of Dimensions to Spot Welding Symbols
(Continued)

Desired Welds

Symbol



Spot Welding Symbol Showing Use of Combined Dimensions

(Resistance Spot)

TM #30

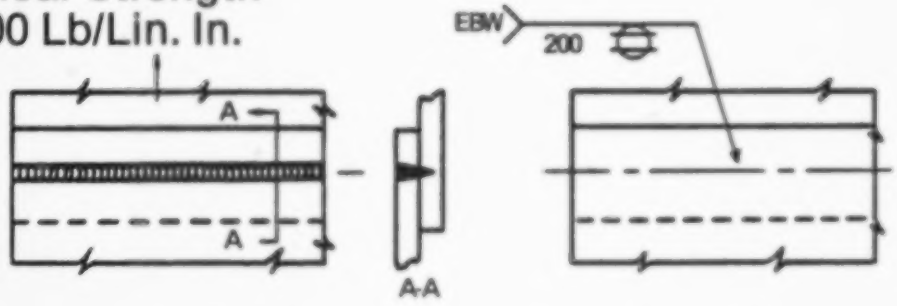
1977

Application of Dimensions to Seam Welding Symbols

Strength of Seam Welds

(Electron Beam Seam)

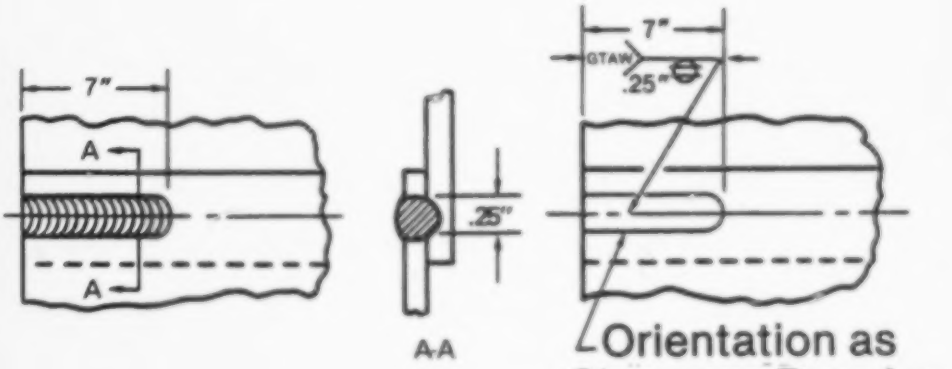
Minimum Acceptable
Shear Strength
200 Lb/Lin. In.



Desired Weld Symbol

Extent of Seam Welds

(Gas Tungsten-Arc Seam)



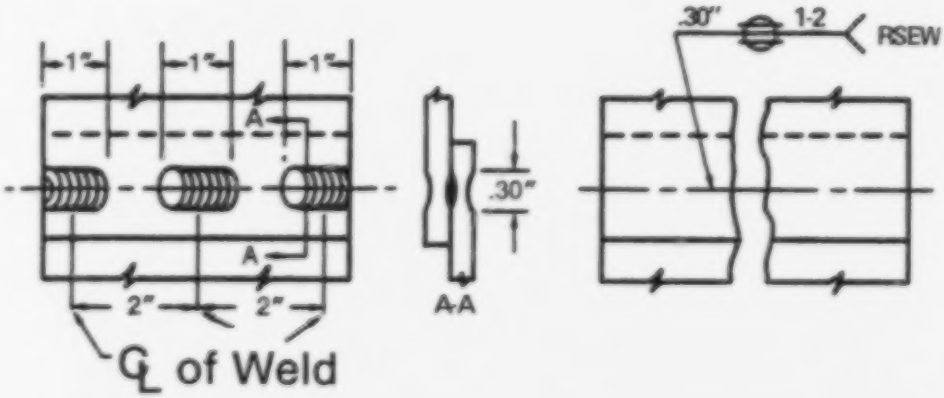
Desired Weld Symbol

Application of Dimensions to Seam Welding Symbols

(Continued)

Size, Length and Pitch of Intermittent Seam Welds

(Resistance Seam)



Desired Weld

Symbol

1979

ARC WELDING
UNIT I

JOB SHEET #1 — START, STOP, AND RESTART A BEAD

I. Equipment and materials

A. Piece of metal, 4 inches square, 1/4- to 3/8-inch thick

B. Welding machine

C. Electrode holder with lead

D. Ground clamp with lead

E. Shield or helmet

F. Leather gloves

G. Electrodes

H. Wire brush

I. Protective clothing

II. Procedure

A. Prepare metal for welding

B. Put on shield or helmet

C. Strike arc 1 inch from edge where bead is to begin (Figures 29 and 30)

FIGURE 29

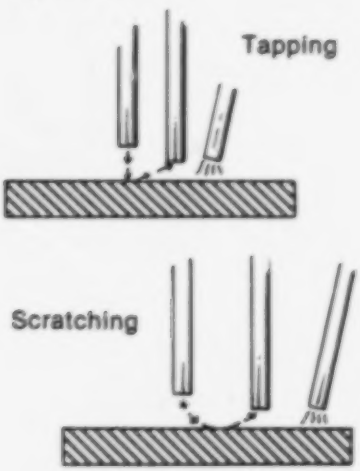
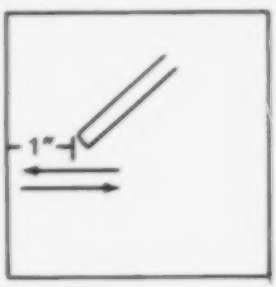


FIGURE 30



JOB SHEET #1

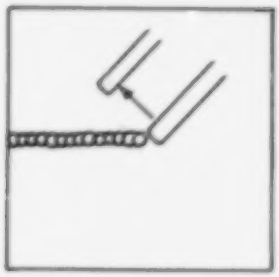
D. When arc burns brightly, move to edge, maintaining correct arc length; begin forming puddle

E. Move across metal 2 inches

F. Move electrode back through puddle, and lift up to stop bead (Figure 31)

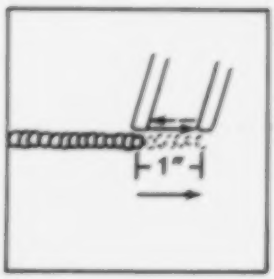
(NOTE: Moving electrode through puddle will prevent cracks from forming in the puddle.)

FIGURE 31



G. Strike arc about 1 inch in front of crater to restart (Figure 32)

FIGURE 32



H. When arc burns brightly, move back through crater, and continue the bead

(NOTE: Moving back through the crater is necessary in order for beads to blend with one another without a change in continuity.)

I. Clean work area; put away all equipment and materials

ARC WELDING
UNIT I

JOB SHEET #2 — CONSTRUCT A PAD WELD

I. Equipment and materials

A. Piece of metal, 4 inches square, 1/4- to 3/8-inch thick

B. Welding machine

C. Electrode holder with lead

D. Ground clamp with lead

E. Shield or helmet

F. Leather gloves

G. Electrodes

H. Safety goggles

I. Chipping hammer

J. Wire brush

K. Protective clothing

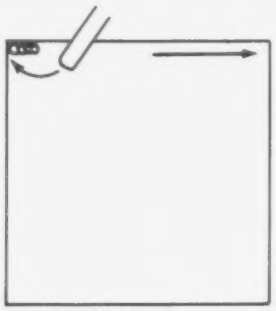
II. Procedure

A. Prepare metal for welding

B. Put on shield or helmet

C. Strike arc, and move to point to begin pad (Figure 33)

FIGURE 33



JOB SHEET #2

D. Lay a straight bead across the plate, using an oscillating motion

(NOTE: When using an E-6011 electrode, you must manipulate the rod to run a bead. Ask your instructor to explain this process.)

E. Hold electrode at a 15- to 30-degree angle in direction of travel; to maintain correct arc length, lower electrode as rod burns away (Figure 34)

(NOTE: There should be 90 degrees on each side of the electrode. See Figure 35.)

FIGURE 34

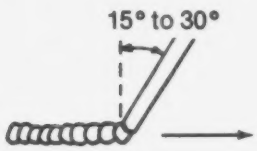
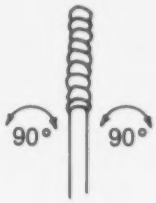


FIGURE 35



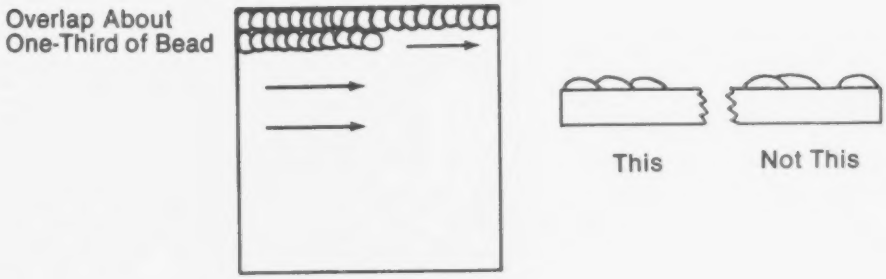
F. Move electrode steadily from left to right across pad

G. Clean slag from each bead before starting next one

(CAUTION: If you remove your shield or helmet, always be sure to put on safety goggles.)

H. Run beads, overlapping each bead until pad is full (Figure 36)

FIGURE 36



I. Before chipping, let each bead cool until slag is black

J. Run additional bead layers until desired thickness is obtained

K. Clean work area; put away all equipment and materials

ARC WELDING
UNIT I

JOB SHEET #3 — CONSTRUCT A BUTT WELD

I. Equipment and materials

A. Two metal pieces, 3 by 6 inches, 1/4- to 3/8-inch thick

B. Welding machine

C. Electrode holder with lead

D. Ground clamp with lead

E. Shield or helmet

F. Leather gloves

G. Electrodes

H. Safety goggles

I. Chipping hammer

J. Wire brush

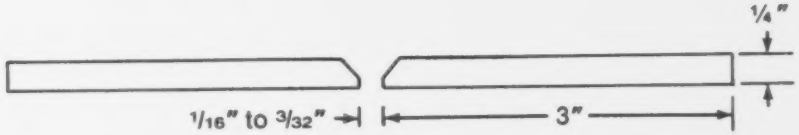
K. Protective clothing

II. Procedure

A. Prepare metal to be welded (Figure 37)

(NOTE: If metal thickness is over 1/8 inch, the edges should be beveled.)

FIGURE 37



B. Place two pieces of metal parallel to each other

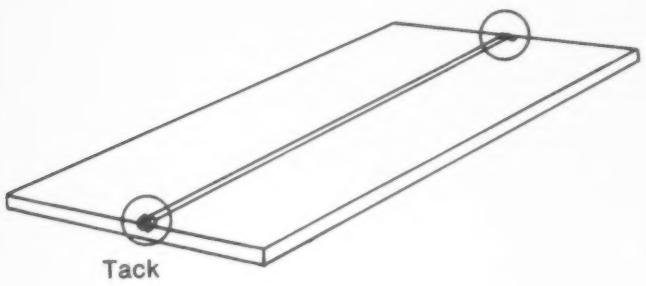
(NOTE: Leave a space of 1/16 to 3/32 inch between them.)

C. Put on shield or helmet

JOB SHEET #3

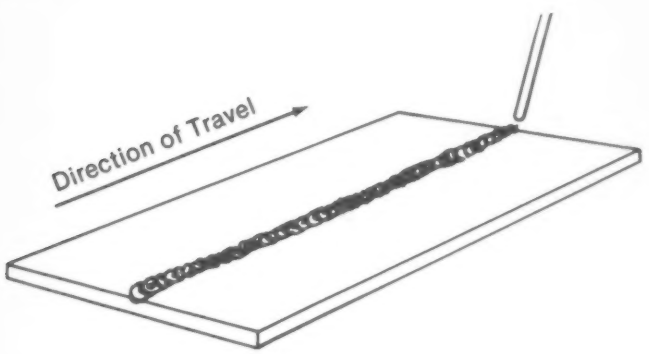
D. Strike an arc, and tack-weld pieces together at both ends (Figure 38)

FIGURE 38



E. Complete weld using a single pass (Figure 39)

FIGURE 39



F. Chip slag; brush the weld

(CAUTION: If you remove your shield or helmet, always be sure to put on safety goggles.)

G. Clean work area; put away all equipment and materials

ARC WELDING
UNIT I

JOB SHEET #4 — CONSTRUCT A LAP-JOINT FILLET WELD IN THE OVERHEAD POSITION

I. Equipment and materials

- A. Arc-welding station and required tools
- B. Two pieces mild-steel plate, 2 by 6 inches, 1/4- to 3/8-inch thick
- C. Electrode E-6010, 1/8- or 5/32-inch
  1. 1/8-inch — 75 to 130 amperes
  2. 5/32-inch — 90 to 175 amperes
- D. Current DCRP + at electrode
- E. Chipping hammer
- F. Wire brush
- G. Leather gloves
- H. Shield or helmet
- I. Protective clothing

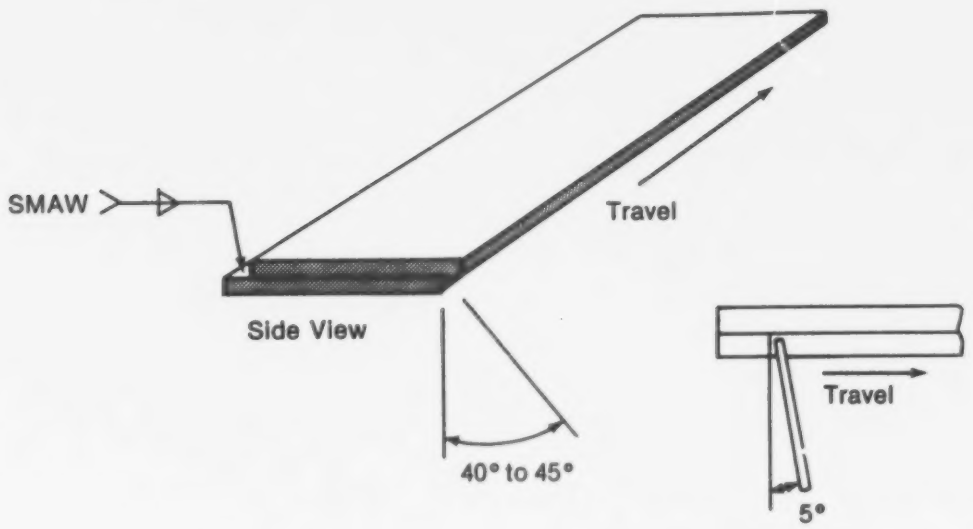
II. Procedure

- A. Adjust welding machine to correct current and amperage setting
- B. Put on shield or helmet
- C. Prepare metal, and tack plate together for a 90-degree lap joint in the overhead position

JOB SHEET #4

D. Position electrode 40 to 45 degrees out from vertical and inclined 5 degrees in direction of travel (Figure 40)

FIGURE 40



E. Strike arc, and establish a puddle evenly on both pieces

(NOTE: Be sure to get good penetration into root of joint without undercutting or overlapping plates. Some form of whipping motion will be needed.)

F. After depositing first bead (root pass), the weld should be chipped, brushed clean, and checked for bead appearance

G. Deposit additional beads if necessary as stringers or weaves

H. Clean plates

I. Clean work area; put away all equipment and materials

ARC WELDING
UNIT I

JOB SHEET #5 — CONSTRUCT A T-JOINT FILLET WELD IN THE VERTICAL UP POSITION

I. Equipment and materials

- A. Arc-welding station and required tools
- B. Two pieces mild-steel plate, 2 by 6 inches, 1/4- to 3/8-inch thick
- C. Electrode E-6010, 1/8- or 5/32-inch
  1. 1/8-inch — 75 to 130 amperes
  2. 5/32-inch — 90 to 175 amperes
- D. Current DCRP + at electrode
- E. Chipping hammer
- F. Wire brush
- G. Leather gloves
- H. Shield or helmet
- I. Protective clothing

II. Procedure

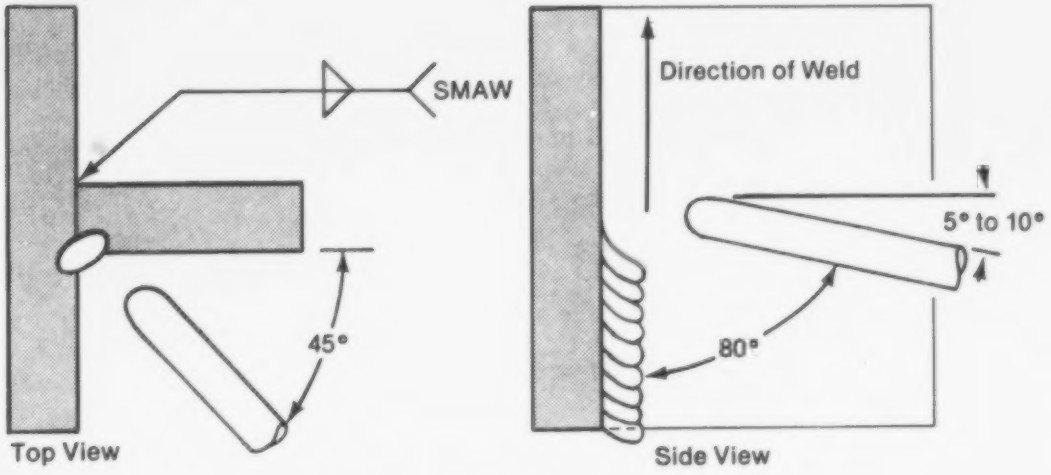
- A. Adjust welding machine to correct current and amperage setting
- B. Put on shield or helmet
- C. Prepare metal, and tack in vertical position; remove slag
- D. Strike arc at bottom of joint; hold a high arc length for one to two seconds to heat plates

JOB SHEET #5

E. Position electrode in middle of joint, making a 45-degree angle with each plate and holding electrode 5 to 10 degrees down from horizontal (Figure 41)

FIGURE 41

T Joint



Electrode Position of Vertical Up T-Joint

F. Deposit weld upward using some form of up and down whipping motion

(NOTE: Bead uniformity depends upon proper timing and manipulation of electrode. Check with instructor for correct procedures.)

G. Remove slag and clean thoroughly after each pass

H. Alternate sides to minimize distortion

(NOTE: Check with instructor at this point. Upon receiving instructor's approval, additional beads may be stringers or some form of weave bead.)

I. Clean work area; put away all equipment and materials

ARC WELDING
UNIT I

JOB SHEET #6 — CONSTRUCT A SQUARE-GROOVE BUTT-JOINT WELD IN THE VERTICAL DOWN POSITION

I. Equipment and materials

- A. Arc-welding station and required tools
- B. Two pieces mild-steel plate, 3 by 6 inches, 1/8- to 3/16-inch thick
- C. Electrode E-6010, 1/8- or 5/32-inch
  1. 1/8-inch — 75 to 130 amperes
  2. 5/32-inch — 90 to 175 amperes
- D. Current DCRP + at electrode
- E. Chipping hammer
- F. Wire brush
- G. Leather gloves
- H. Shield or helmet
- I. Protective clothing

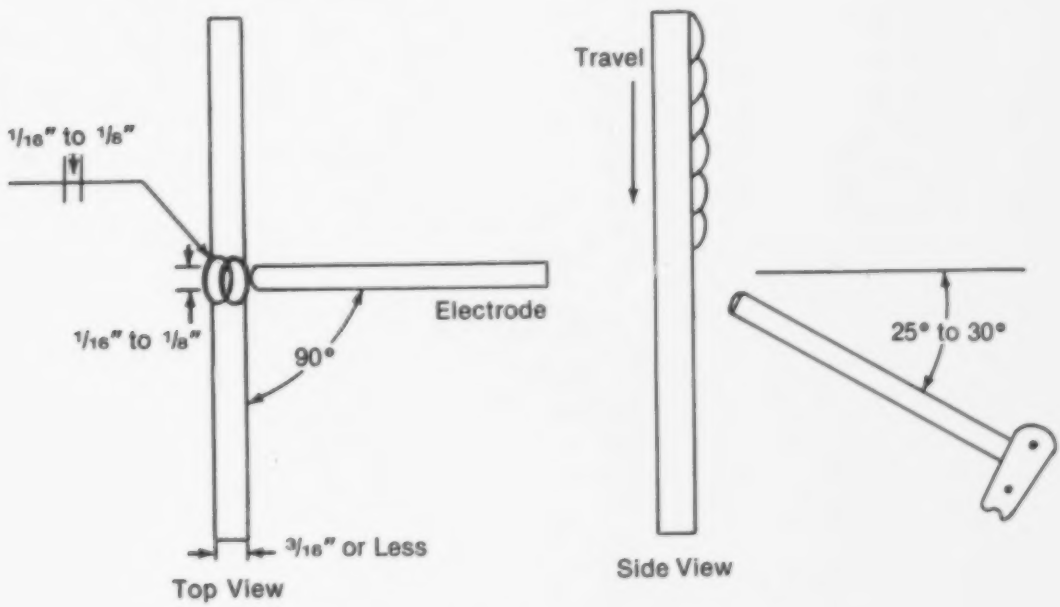
II. Procedure

- A. Adjust welding machine to correct current and amperage setting
- B. Put on shield or helmet
- C. Prepare metal and tack, leaving a 1/16- to 1/8-inch root gap in vertical position

JOB SHEET #6

D. Position electrode in middle of joint and down 25 to 30 degrees from horizontal (Figure 42)

FIGURE 42



E. Strike arc at top of plates; hold a high arc length for one to two seconds to heat plates and prevent cold laps

F. Weld down, holding a short arc length and using some form of whipping motion

G. Remove all slag from face and root; inspect bead thoroughly for penetration and even fusion with both plates

H. Start at top of reverse side and run second bead using same technique as in first pass

ARC WELDING
UNIT I

TEST

NAME _____ SCORE _____

1. Match terms associated with arc welding to their correct definitions. Write the correct numbers in the blanks. Terms and definitions are continued on the following page.

_____a.	Flow of current across a narrow gap, usually from tip of electrode to base metal	1. Arc welding
_____b.	Process of heating metal to a molten state and allowing it to cool	2. Bevel
_____c.	Joining of two or more pieces of metal by fusion process	3. Puddle
_____d.	Depression at termination of weld	4. Crater
_____e.	Single longitudinal progression of a welding operation along a joint or weld deposit	5. Wire core
_____f.	Metal rod that conducts a current from electrode holder to base metal	6. Arc
_____g.	Angular cut made on the vertical edge of base metal to allow better weld penetration	7. Pass
_____h.	Weld between two metal joints on the same plane	8. Butt joint
_____i.	Portion of a weld that is molten at the place heat is applied	9. Fusion process
_____j.	Metal center of electrode	10. Electrode
_____k.	Cables leading from ground clamp and holder to machine	11. Flux
_____l.	Coating on outside of electrode; chemical used to promote fusion during welding process	12. Lead
_____m.	Gas given off by melting of electrode flux	13. Gaseous shield

TEST

_____n. Nonmetallic porous material trapped in weld metal or between weld metal and base metal

_____o. That part of base metal altered by heat from welding, brazing, or cutting operations

_____p. Distance from original surface of base metal to that point at which fusion ceases

_____q. Electrode with low hydrogen content; used when cracking is a potential problem

_____r. Capable of being drawn or stretched

_____s. Distance from end of electrode to point where arc makes contact with work surface

_____t. Lightly ruffled or covered with small waves

_____u. Capable of being worked into a different shape or form

_____v. Condition of being positive (+) or negative (−), as the ends of a magnet or electrical mechanism

14. Heat line (heat-affected zone)
15. Penetration
16. Low-hydrogen electrode
17. Slag inclusion
18. Rippled
19. Malleable
20. Arc length
21. Ductile
22. Polarity

2. Write meanings of abbreviations associated with arc welding.

a. AC—_____

_____

b. AWS—_____

_____

c. DC—_____

_____

d. OSHA—_____

_____

e. psi—_____

_____

TEST

3. State ten safety precautions to observe when welding.

   a. _____

   b. _____

   c. _____

   d. _____

   e. _____

   f. _____

   g. _____

   h. _____

   i. _____

   j. _____

4. Name types of arc-welding machines.

   a. _____

   b. _____

   c. _____

   d. _____

   e. _____

5. Select from the following list common tools and equipment used in arc welding. Write an "X" in the blank before each correct answer.

   _____a. Shield or helmet

   _____b. Safety goggles

   _____c. Electrode

   _____d. Oxyacetylene tank

   _____e. Ground clamp with lead

   _____f. Welding machine

TEST

_____g. Welding rod

_____h. Electrode holder with lead

_____i. Leather gloves

_____j. Tip cleaner

_____k. Protective clothing

6. Match to their correct definitions terms associated with welding materials. Write the correct numbers in the blanks.

_____a. Steel containing from 0.2 to 0.5 percent carbon

_____b. Metal to be cut or welded

_____c. Steel containing 0.2 percent or less carbon

_____d. Hardest known metal; used for making very strong alloy steels with manganese or chromium

_____e. Commercial alloy of iron, carbon, and silicon that is cast in a mold and is hard, brittle, nonmalleable, and incapable of being hammer-welded

_____f. Bluish silver-white, malleable, ductile, light, trivalent metallic element

_____g. Mixture of two or more elements, of which at least one is a metal

1. Alloy
2. Aluminum
3. Base metal
4. Cast iron
5. Low-carbon steel
6. Mild steel
7. Vanadium

7. List three types of electrodes.

a. _____

b. _____

c. _____

8. Select from the following list common sizes of electrodes used in arc welding. Write an "X" in blank before each correct answer.

_____a. 3/32 inch

_____b. 1/8 inch

1995

TEST

_____c. 1/4 inch

_____d. 5/16 inch

_____e. 5/32 inch

_____f. 3/16 inch

9. Interpret meanings of numbers in the AWS electrode classification system.

EXAMPLE: E-6021

a. E — _____

b. First two digits — _____

_____

c. Third digit — _____

1) _____

2) _____

3) _____

d. Fourth or last digit — _____

_____

10. Distinguish between reverse and straight polarity. Write an "X" in the blank before the statement that represents reverse polarity.

_____a. Current flows from electrode to base metal

_____b. Current flows from base metal to electrode

11. Select from the following list factors that determine correct polarities to use. Write an "X" in the blank before each correct answer.

_____a. Electrode

_____b. Current

_____c. Type of flux on electrode

_____d. Color of electrode

_____e. Brand of electrode

1996

TEST

12. Select from the following list purposes of electrode flux. Write an "X" in the blank before each correct answer.

_____a. Floating impurities out of puddle

_____b. Protecting electrode

_____c. Forming slag and slowing down cooling

_____d. Increasing welding speed

_____e. Shielding electrode from air

_____f. Stabilizing arc

_____g. Adding slag elements to weld metal

_____h. Improving quality of weld

13. List five factors to consider when selecting electrodes.

a. _____

b. _____

c. _____

d. _____

e. _____

14. Describe effects of raising and lowering welding machine amperes.

a. Raising amperes — _____

_____

b. Lowering amperes — _____

_____

15. Name methods of striking an arc.

a. _____

b. _____

TEST

16. Select from the following list characteristics of proper arc length. Write an "X" in the blank before each correct answer.

_____a. Arc length same size as bead

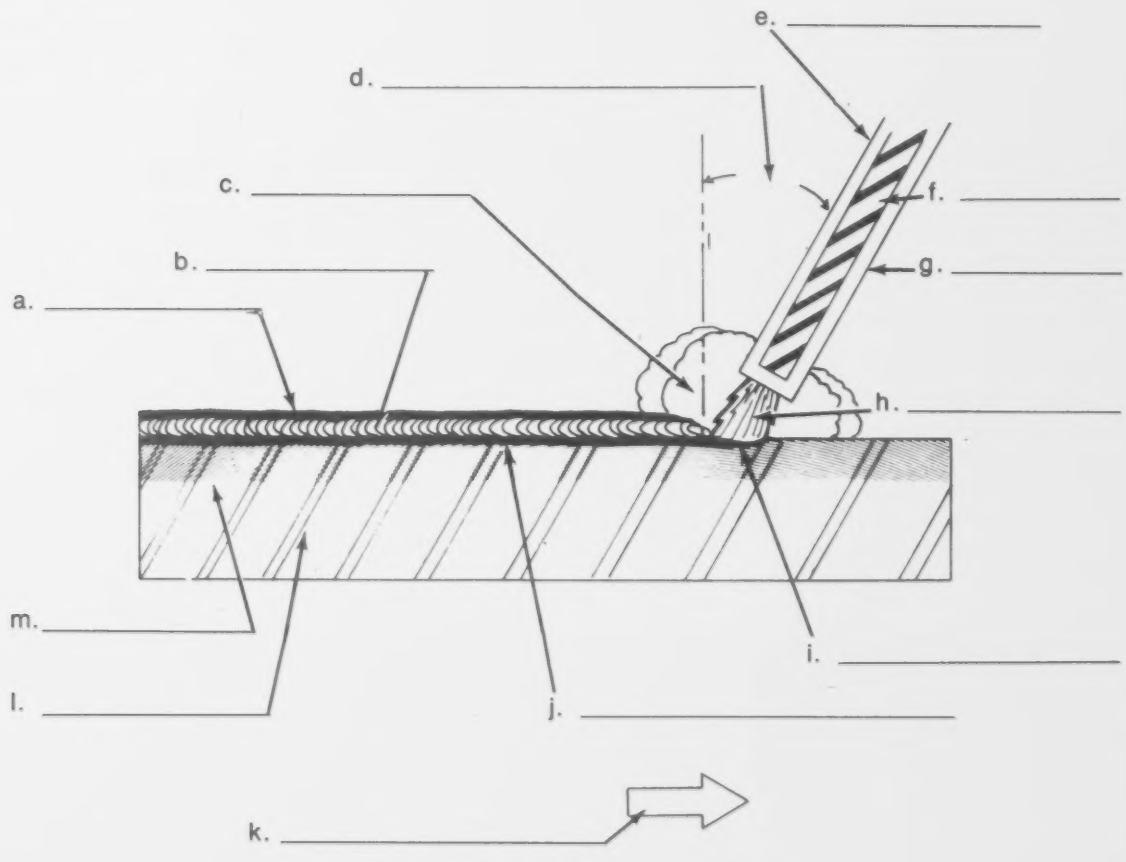
_____b. Arc length making steady hum at welder and frying sound at arc

_____c. End of electrode same distance from base metal as diameter of electrode

_____d. End of electrode touching base metal

17. Identify parts of the welding process illustrated below. Write the correct names in the blanks.

Electrode	**Wire core**	**Angle of electrode**	**Base metal**
Coating (flux)	**Arc**	**15 to 30 degrees**	**Crater**
Penetration	**Weld**	**Heat lines**	
Slag	**Direction of travel**	**Gaseous shield**	

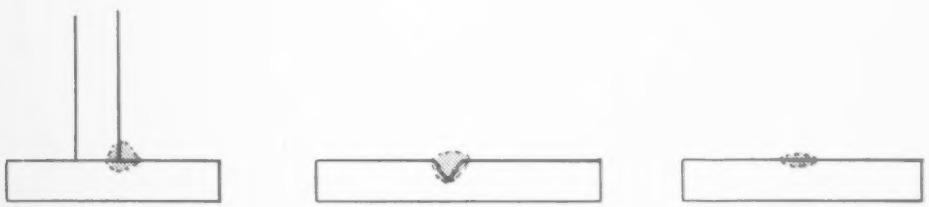


TEST

18. Match types of welds to their correct descriptions. Write the correct numbers in the blanks.

_____a.	Weld made by one pass of electrode	1. Tack weld
_____b.	Temporary weld made to hold parts in alignment until final welds are made	2. Bead weld
_____c.	Weld made in groove formed by two beveled pieces of metal	3. Fillet weld
_____d.	Weld made in corner or angle formed by two pieces of metal with welded surfaces at approximately 90-degree angles to each other	4. Groove weld

19. Label types of welds illustrated below.

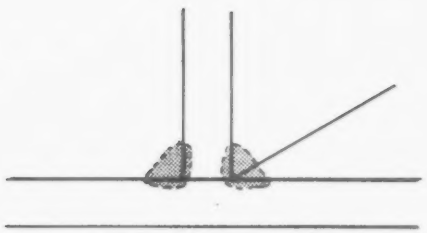


a. _____ b. _____ c. _____

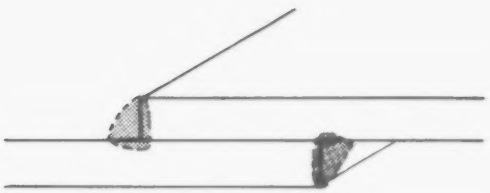
20. Label types of weld joints illustrated below and on the following page.

a. _____ b. _____

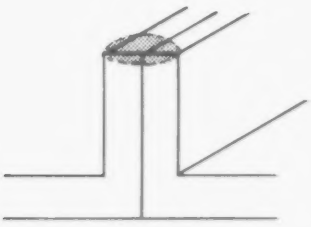
TEST



c. _____



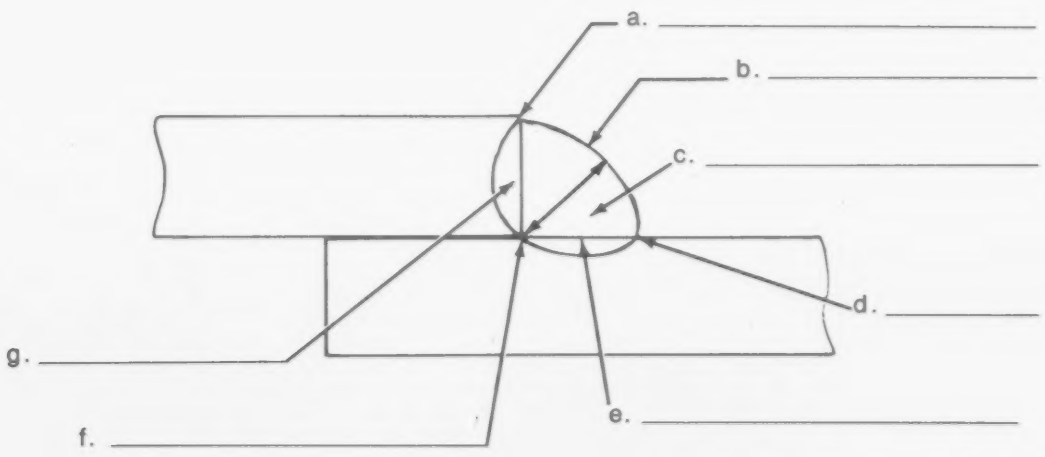
d. _____



e. _____

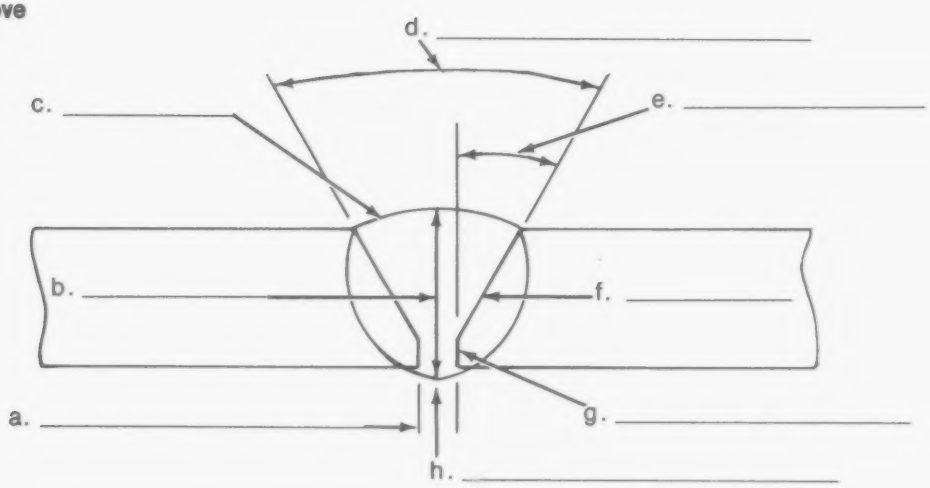
21. Label parts of groove and fillet welds illustrated below and on the following page.

Fillet



TEST

Groove



22. List positions used in arc welding.

a. _____

b. _____

c. _____

d. _____

23. List three reasons for poor welds.

a. _____

b. _____

c. _____

24. List four types of electrode motions (rod manipulations).

a. _____

b. _____

c. _____

d. _____

TEST

25. State three characteristics of a good weld.

a. _____

b. _____

c. _____

26. Match elements of welding symbols to their correct descriptions. Write the correct numbers in the blanks.

_____a.	Includes specification, process, or other reference	1. Reference line top
_____b.	Indicate type of weld	2. Reference line bottom
_____c.	Contains information for weld on side opposite arrow	3. Arrow
_____d.	Indicate method of finish	4. Basic weld symbols
_____e.	Indicate contour, backing or spacer material, melt-through, field weld, weld all around	5. Dimensions and other data
_____f.	Contains information for weld on arrow side	6. Supplementary symbols
_____g.	Points toward joint	7. Finish symbols
_____h.	Details information pertinent to weld; shown inside tail	8. Tail
_____i.	Indicate size, length of weld; shown on same side of reference line as weld symbol	9. Specification, process, or other reference

27. Draw symbols showing location of weld. Any weld symbol may be used.

a. Weld on arrow side of joint

b. Weld on other side of joint

TEST

c. Weld on both sides of joint

28. Identify basic weld symbols. Write the correct names in the blanks.

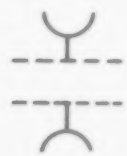
Edge flange	**Flared V-groove**	**Square groove**	**Plug or slot**
Corner flange	**Flared bevel groove**	**Scarf groove**	**Spot or projection**
Surfacing	**U-groove**	**V-groove**	**Seam**
J-groove	**Bevel groove**	**Fillet**	**Back or backing**

a. _____

b. _____

c. _____

d. _____

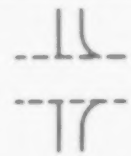


e. _____

f. _____

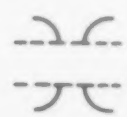
g. _____

h. _____

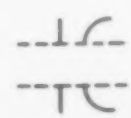


i. _____

j. _____



k. _____



l. _____

TEST

m. _____

n. _____

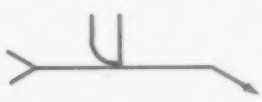
o. _____

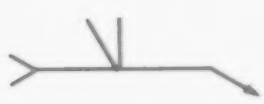
p. _____

29. Distinguish between correct and incorrect drawings of symbols with one vertical side. Write a "C" in the blank before each correct drawing.

_____a.

_____b.

_____c. 

_____d. 

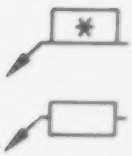
_____e.

_____f.

TEST

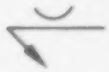
30. Label supplementary symbols.

a. _____



b. _____

c. _____



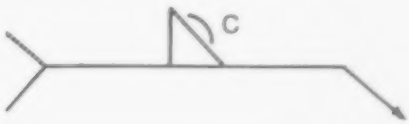
d. _____

e. _____

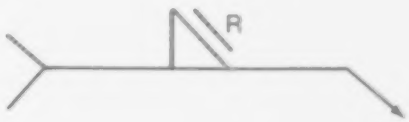
f. _____

g. _____

31. Interpret finish symbols used with contour symbols. Write the correct finish methods in the blanks.



a. _____

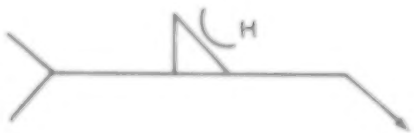


b. _____

TEST

c. _____

d. _____



e. _____

(NOTE: Test question 32 lists the job sheets. They are an important part of this test. If they have not been completed, check with your instructor.)

32. Demonstrate the ability to

a. Start, stop, and restart a bead.

b. Construct a pad weld.

c. Construct a butt weld.

d. Construct a lap-joint fillet weld in the overhead position.

e. Construct a T-joint fillet weld in the vertical up position.

f. Construct a square-groove butt-joint weld in the vertical down position.

ARC WELDING
UNIT I

ANSWERS TO TEST

1.	a.	6	g.	2	m.	13	s.	20
	b.	9	h.	8	n.	17	t.	18
	c.	1	i.	3	o.	14	u.	19
	d.	4	j.	5	p.	15	v.	22
	e.	7	k.	12	q.	16		
	f.	10	l.	11	r.	21		

2. a. AC — Alternating current; electric current that reverses its direction at regular intervals

   b. AWS — American Welding Society

   c. DC — Direct current; electric current flowing in one direction only and mostly constant in value

   d. OSHA — Occupational Safety and Health Act

   e. psi — Pounds per square inch

3. Answer should include any ten of the following

   a. Do not look at arc or reflection without eye protection

   b. Do not wear shield or helmet that is in bad condition

   c. Do not chip slag without wearing safety goggles

   d. Wear proper protective clothing

   e. Do not strike an arc until you have taken all safety precautions

   f. Do not weld around combustible or flammable materials

   g. Do not pick up hot metals with bare hands

   h. Be sure that confined areas are properly ventilated

   i. Disconnect plug before checking welding machine

ANSWERS TO TEST

j. Do not leave electrode holder on welding table or in direct contact with grounded metal

k. Do not use worn or frayed cables

l. Be sure that floor is dry; do not stand in water when welding

m. Keep work area clean

n. Keep tools and materials in proper locations

o. Dispose of electrode stubs properly

4. a. Alternating-current (AC) transformer welder

b. Direct-current (DC) welder

c. Motor generator

d. Engine generator

e. AC/DC transformer rectifier

5. a, b, c, e, f, h, i, k

6.

a.	6	e.	4
b.	3	f.	2
c.	5	g.	1
d.	7		

7. Answer should include any three of the following

a. Mild steel

b. Low-alloy steel

c. Nickel steel

d. Chromium/molybdenum steel

e. Manganese/molybdenum steel

f. Nickel/manganese/molybdenum steel

g. Nickel/molybdenum/vanadium steel

h. Aluminum

i. Copper aluminum (aluminum bronze)

j. Lead-bronze

k. Phosphor bronze

ANSWERS TO TEST

8. a, b, e, f

9. a. E — Electric arc welding

   b. First two digits — Minimum tensile strength deposited in thousands of pounds per square inch

   c. Third digit — Welding position

      1) One — Indicates all positions

      2) Two — Indicates flat and horizontal only

      3) Three — Indicates flat only

   d. Fourth or last digit — Special characteristics and uses of the electrode

10. b

11. a, c

12. a, c, d, f, h

13. Answer should include any five of the following

   a. Plans and specifications

   b. Physical and chemical properties of base metal

   c. Composition of base metal

   d. Thickness and shape of base metal

   e. Welding position

   f. Welding current

   g. Joint design and fit-up

   h. Production efficiency and job conditions

2009

ANSWERS TO TEST

14. Description should include the following

    a. Raising amperes — Produces more heat; increases penetration

    b. Lowering amperes — Produces less heat; decreases penetration

15. a. Scratching

    b. Tapping

16. b, c

17. a. Slag
    b. Weld
    c. Gaseous shield
    d. Angle of electrode 15 to 30 degrees
    e. Electrode
    f. Wire core
    g. Coating (flux)
    h. Arc
    i. Crater
    j. Penetration
    k. Direction of travel
    l. Base metal
    m. Heat lines

18. a. 2
    b. 1
    c. 4
    d. 3

19. a. Fillet

    b. Groove

    c. Bead

20. a. Butt
    b. Corner
    c. T
    d. Lap
    e. Edge

2010

ANSWERS TO TEST

21.

	Fillet		**Groove**
a.	Toe	a.	Root opening
b.	Face	b.	Throat
c.	Throat	c.	Face
d.	Toe	d.	Groove angle
e.	Leg	e.	Bevel angle
f.	Root	f.	Groove face
g.	Leg	g.	Root face
		h.	Root

22.
a. Flat
b. Horizontal
c. Vertical
d. Overhead

23. Answer should include any three of the following
a. Incorrect machine adjustment
b. Too large or too small electrode
c. Improper movement of electrode
d. Improper angle of electrode
e. Improper preparation of base metal
f. Incorrect arc length

24. Answer should include any four of the following
a. Small oscillating motion
b. Small circular motion

ANSWERS TO TEST

c. Back-and-forth motion with half circle

d. Figure-eight motion

e. Triangular motion

25. Answer should include any three of the following

a. Smooth edges

b. Correct bead size

c. Even penetration (well fused)

d. Even ripple

e. Clean, bright weld

f. Slight crown

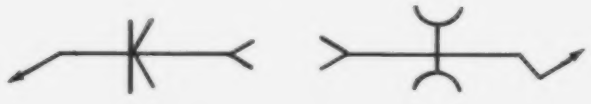
26.

a.	8	f.	2
b.	4	g.	3
c.	1	h.	9
d.	7	i.	5
e.	6		

27. Student may use any weld symbol in the following positions.

a.

b.

c. 

ANSWERS TO TEST

28.

a.	Plug or slot		i.	Corner flange
b.	Square groove		j.	Scarf groove
c.	Edge flange		k.	Flared V-groove
d.	V-groove		l.	Flared bevel groove
e.	U-groove		m.	Seam
f.	Surfacing		n.	Spot or projection
g.	Fillet		o.	Bevel groove
h.	J-groove		p.	Back or backing

29. b, e, f

30.

a.	Melt-through		e.	Weld all around
b.	Backing or spacer material		f.	Field weld
c.	Convex contour		g.	Flush contour
d.	Concave contour			

31.

a. Chipped
b. Rolled
c. Machined
d. Ground
e. Hammered

32. Performance skills evaluated to the satisfaction of the instructor

OXYACETYLENE CUTTING
UNIT II

UNIT OBJECTIVE

After completing this unit, the student should be able to set up, light, adjust, and use an oxyacetylene cutting outfit. The student will show this knowledge by completing job sheets and unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match terms associated with oxyacetylene cutting to their correct definitions.
2. State color codes for oxygen and acetylene.
3. Arrange in order stages in the oxyacetylene cutting process.
4. Identify the parts of an oxyacetylene cutting outfit.
5. Identify the parts of a torch body and cutting attachment.
6. State safety rules for working with oxyacetylene equipment.
7. Identify types of oxyacetylene cutting flames.
8. Distinguish between flashback and backfire.
9. Arrange in order steps to follow in case of flashback.
10. Select from a list causes of backfire.
11. Match common cutting-torch tips to their correct uses.
12. Identify a multiflame heating nozzle (rosebud) and tip.
13. Describe uses of a multiflame heating nozzle (rosebud).
14. Demonstrate the ability to
    a. Set up equipment for oxyacetylene cutting.
    b. Turn on, light, adjust to a neutral flame, and turn off oxyacetylene cutting equipment.
    c. Cut mild steel at a 90-degree angle, stop, and restart the cut.
    d. Cut round stock.
    e. Cut cable.

OXYACETYLENE CUTTING
UNIT II

SUGGESTED ACTIVITIES

I. Suggested activities

A. Order materials to supplement unit.

1. Films

a. *Flame Cutting*. Color, 20 minutes, MacMillian Films, 1972. Available from MacMillian Films, 34 MacQuesten Parkway South, Mount Vernon, New York 10550, 914/664-5051.

(NOTE: This film provides step-by-step instructions for making straight-line cuts, cutting irregular shapes, beveling plate edges, and making circle cuts. It gives excellent instructions on freehand cutting and oxyacetylene cutting torch.)

b. *The Cutting Torch — Flame Cutting*. Color, 18 minutes, BFA Educational Media, 1972. Available from BFA Educational Media, 468 Park Avenue South, New York, New York 10016, 212/684-5910.

(NOTE: This film covers the many aspects of tip selection and the procedures for using the torch.)

c. *Don't Push Your Luck*. Color, 12 minutes, Harvest Films, 1978. Available from Harvest Films, Inc., 309 5th Avenue, New York, New York 10016, 212/648-7950.

(NOTE: Bill Frank, the actual victim, recreates his real-life blinding accident. He delivers to employees a powerful safety message on face and eye protection.)

2. Slide/cassette programs

a. *There's Something in the Air*. Thirty slides with cassette, National Safety Council, n.d. Available from National Safety Council, P.O. Box 11933, Chicago, Illinois 60611, 312/527-4800.

(NOTE: This program tells workers how to protect themselves from contaminated air — fogs, mists, fumes, gases, smokes, sprays, and vapors — that could be harmful to their lungs.)

SUGGESTED ACTIVITIES

b. *Oxyacetylene Cutting Explained.* Two color filmstrips, 2 cassettes, 12 to 13 minutes each, Bergwall Productions, Inc., n.d. May be purchased from Bergwall Productions, 839 Steward Avenue, P.O. Box 238, Garden City, New York 11530. Call toll-free 800/645-3565.

(NOTE: Part 1, *Setting Up Equipment,* explains cutting operation: cutting tip, attaching tip to torch body, lighting and testing flame, purging the line and shutting down the unit. Part 2, *Specialized Oxyacetylene Cutting,* demonstrates torch angle, correct cutting procedure, lighting and testing the flame, cutting thin and heavy stock, chamfering, constructing and using guide for cutting a circle, and piercing stock.)

B. Obtain transparencies.

(NOTE: Transparencies are available from AGC and CIMC.)

C. Gather equipment and materials for job sheet demonstrations.

D. Get color flame charts from welding supplier to show types of flames.

E. Contact local welding supplier for materials on cutting techniques, pressurized gas, safety equipment, and other items of interest.

F. Provide students with objective sheet.

G. Discuss unit and specific objectives.

H. Provide students with information and job sheets.

I. Discuss information sheet.

J. Review first aid for burns.

K. Arrange a field trip for students to observe flame cutting equipment and operations.

L. Demonstrate and discuss procedures outlined in job sheets.

M. Provide alternate jobs if those in job sheets are not practical.

N. Have students demonstrate the ability to use equipment safely and according to the recommended uses.

O. Give test.

P. Complete appropriate section of competency profiles.

(NOTE: Competency profiles are available from AGC and CIMC.)

SUGGESTED ACTIVITIES

II. Instructional materials

A. Objective sheet

B. Suggested activities

C. Information sheet

D. Transparency masters

1. TM #1 — Oxygen Regulator Gauges
2. TM #2 — Acetylene Regulator Gauges

E. Job sheets

1. Job Sheet #1 — Set Up Equipment for Oxyacetylene Cutting
2. Job Sheet #2 — Turn On, Light, Adjust to a Neutral Flame, and Turn Off Oxyacetylene Cutting Equipment
3. Job Sheet #3 — Cut Mild Steel at a 90-Degree Angle, Stop, and Restart the Cut
4. Job Sheet #4 — Cut Round Stock
5. Job Sheet #5 — Cut Cable

F. Test

G. Answers to test

III. Unit references

A. Althouse, Andrew P., and Carl H. Turnquist, and William A. Bowditch. *Modern Welding*. Homewood, Illinois: Goodheart-Willcox Company, 1965.

B. Hendrix, Laborn J., "Bud." *Heavy Equipment Operator Instructional Materials*, Vol. I. Stillwater, Oklahoma: State Department of Vocational and Technical Education/Curriculum and Instructional Materials Center, and The Associated General Contractors of America, 1981.

C. Hendrix, Laborn J., "Bud." *Millwright Instructional Materials*, Vol. I. Stillwater, Oklahoma: State Department of Vocational and Technical Education/Curriculum and Instructional Materials Center, and The Associated General Contractors of America, 1980.

OXYACETYLENE CUTTING
UNIT II

INFORMATION SHEET

I. Terms and definitions

A. Acetylene — Colorless, gaseous hydrocarbon used in cutting and welding

(NOTE: Other gases are also used in cutting.)

B. Oxygen — Element that is normally a colorless, odorless, and tasteless gas; used in combination with other substances in cutting and welding

C. Oxyacetylene cutting — Flame cutting of metal in which the preheating of the metal is accomplished with a flame produced by an oxyacetylene torch

D. Purge — To remove any foreign material from a system or component by flushing with the gas used in that system

E. psi — Pounds per square inch

F. Combustible — Capable of burning

G. Toxic — Poisonous

H. Journal — That part of a shaft, axle, or spindle that turns in a bearing

I. Flint lighter — Striker used to ignite torch

J. Slag box — Metal container with a layer of water or sand to catch hot material

K. Slag — Metal that melts away during the oxyacetylene cutting process

L. Seizing — Firmly binding cable with soft iron wire

II. Color codes for oxygen and acetylene

A. Oxygen — Green

B. Acetylene — Red

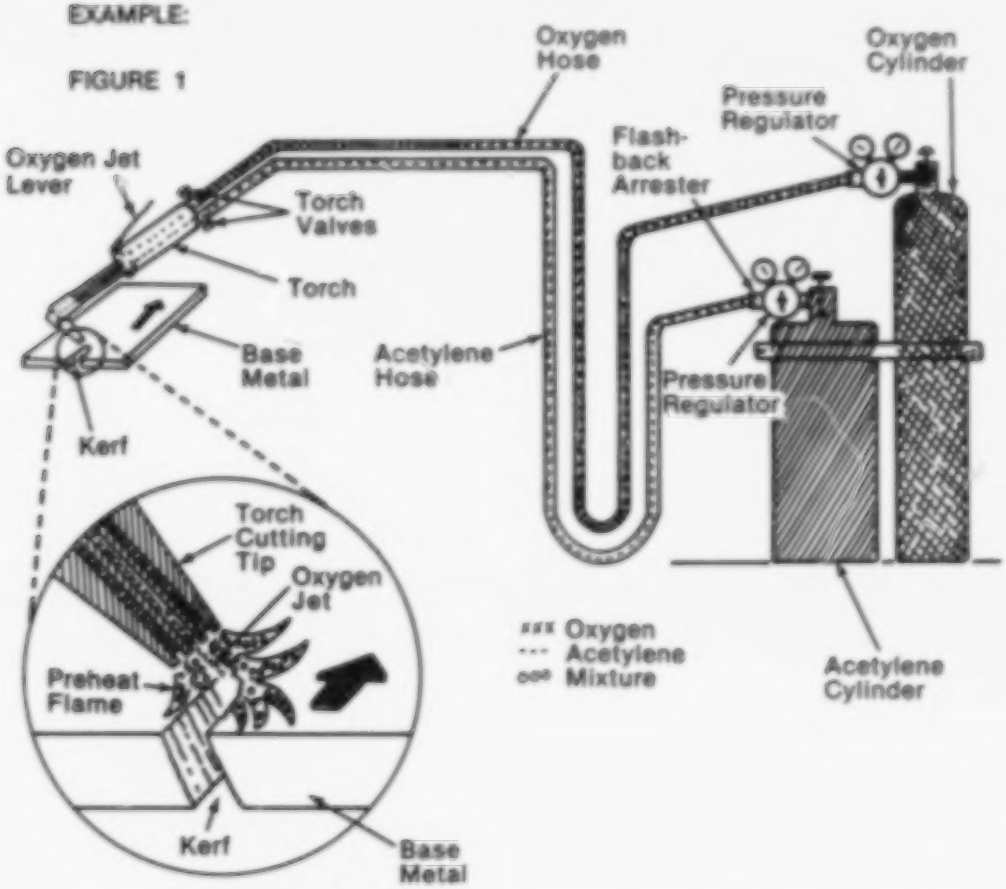
INFORMATION SHEET

III. Stages in the oxyacetylene cutting process (Figure 1)

(NOTE: A flame of oxygen mixed with acetylene [or other fuel gas] heats the base metal; then an oxygen jet cuts the heated metal. Oxyacetylene cutting is one of the most popular methods of cutting and shaping steel.)

EXAMPLE:

FIGURE 1



A. Pressure-regulated acetylene and pressure-regulated compressed oxygen are supplied from two cylinders

(NOTE: Each cylinder has two pressure gauges. The cylinder pressure gauge indicates pressure in the cylinder [high], and the working pressure gauge indicates the pressure of the gas being fed to the torch [low].)

B. Separate, flexible hoses carry gases to torch

(NOTE: Two needle valves control the flow of gas.)

INFORMATION SHEET

C. Operator ignites acetylene gas with spark from flint lighter

D. Operator opens oxygen torch valve, and gases are mixed inside torch

E. Mixture burns at several orifices (preheat orifices) in torch tip

F. Flame heats base metal to a dull, cherry red

G. Operator presses oxygen lever, and jet of oxygen rushes out of cutting orifice

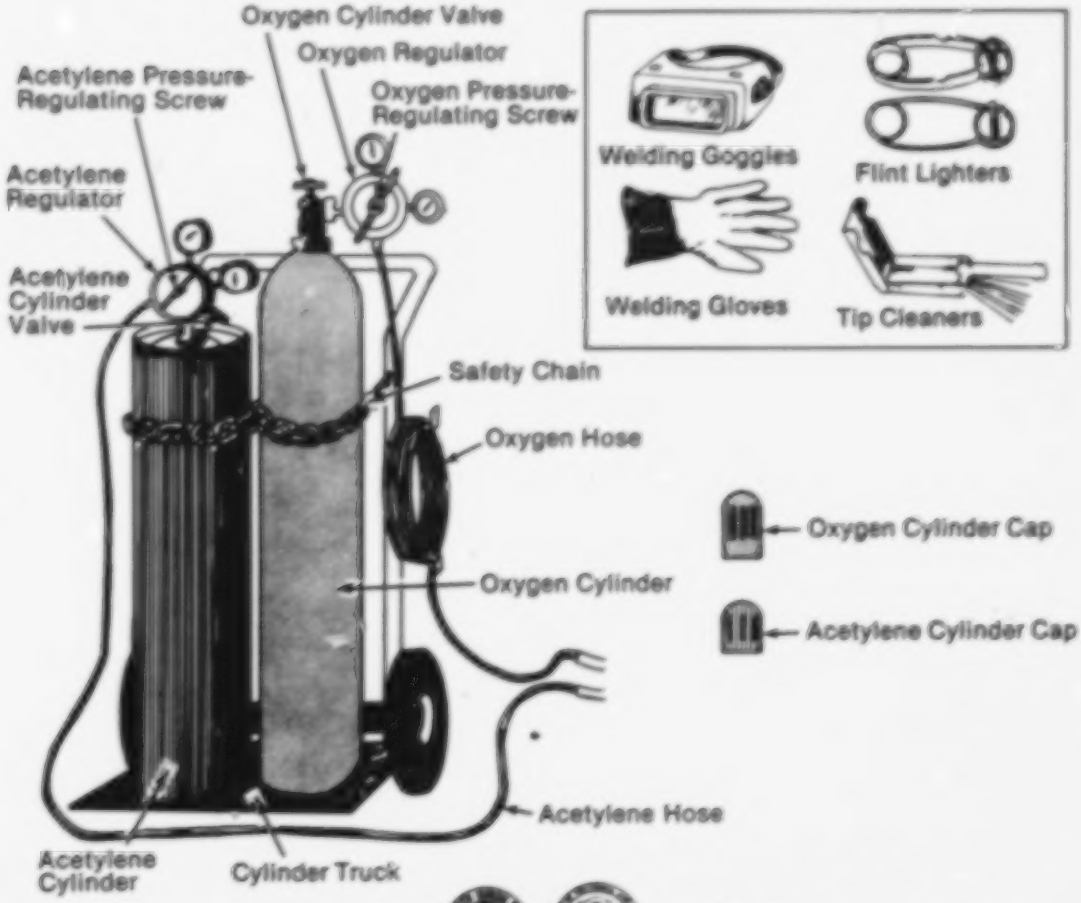
H. Oxygen jet quickly oxidizes the heated base metal and blows it away

I. Removal of material leaves a cut in the metal

IV. Parts of an oxyacetylene cutting outfit (Figure 2; Transparencies #1 and #2)

(NOTE: As an added safety feature, some outfits are equipped with antiflashback valves between regulator and torch.)

FIGURE 2

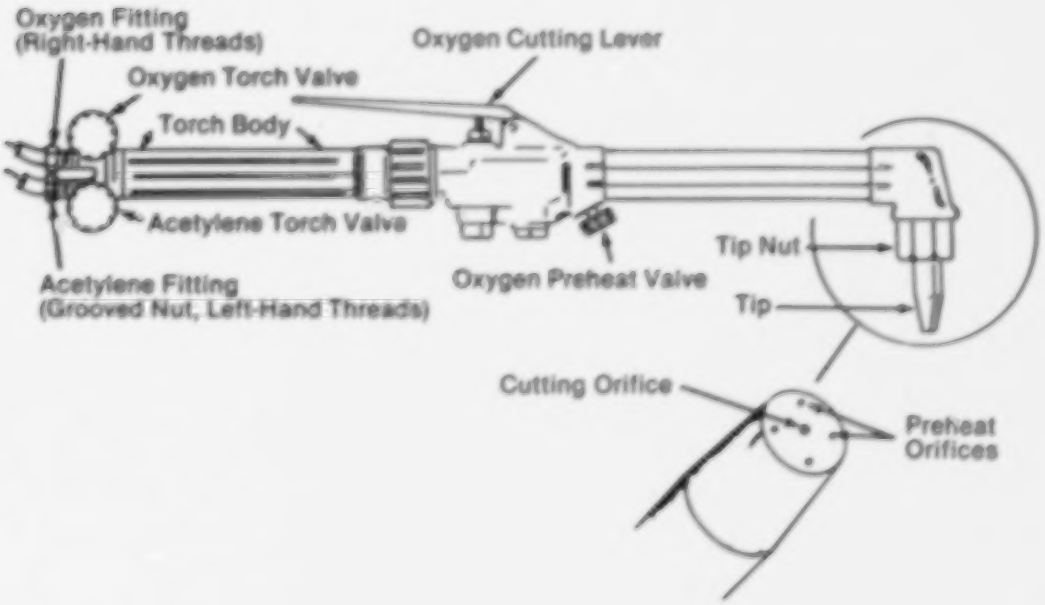


INFORMATION SHEET

V. Parts of a torch body and cutting attachment (Figure 3)

(NOTE: The preheat orifices heat metal to a kindling point of approximately 1,600°F [755°C]. The cutting orifice removes oxidized metal.)

FIGURE 3



VI. Safety rules for working with oxyacetylene equipment

(NOTE: Instructor may add other safety rules. The chief dangers of oxyacetylene cutting are burns and toxic fumes. Pay attention at all times, and notice how you feel.)

(CAUTION: If you feel dizzy or nauseated or if you have blurred vision, stop cutting and get some fresh air.)

A. Make sure that either a foam or a multipurpose dry-chemical fire extinguisher is readily available and in working condition

INFORMATION SHEET

B. Wear welding goggles, gloves, and protective clothing

(CAUTION: Keep gloves, hands, and clothing free of oil and grease.)

C. Wear gloves to handle hot metal

D. Use open torch only in a well-ventilated place

E. Avoid breathing toxic fumes

EXAMPLES: Galvanized metal fumes, some paint fumes

F. Do not leave a burning torch unattended

G. Secure cylinders in a safe place

(NOTE: Secure cylinders to protect valves and regulators and to prevent injuries.)

H. Cut or weld at least 5 feet from cylinders

I. Always use regulators; do not use oxygen or acetylene directly from cylinders

(NOTE: Be sure that regulators are used only on the cylinders that they were designed to be used on.)

J. Use flint lighters, *not matches,* for lighting torch

K. Use hoses designated for oxygen and acetylene only

L. Do not use oil on regulators, torches, fittings, or any equipment surface that may come in contact with oxygen

(CAUTION: Never oil or grease oxygen fittings. Substances will unite with a violent explosion.)

M. Do not use compressed oxygen to clean off clothing

(CAUTION: Do not confuse compressed oxygen with compressed air. Oxygen speeds up combustion, and oxygen-soaked clothing needs only a spark to burst into flame.)

N. Do not breathe compressed oxygen directly from cylinder or hose

O. Use soapsuds and paintbrush to test connections for leaks

P. Do not use acetylene at pressures higher than 15 pounds per square inch

(CAUTION: Acetylene becomes unstable and highly explosive when pressure is over 15 psi.)

Q. Do not cut or weld directly on gravel or concrete

R. Keep heat, flames, and sparks away from combustibles

S. Do not cut or weld on containers that have been used to store combustible materials unless containers have been properly cleaned and purged

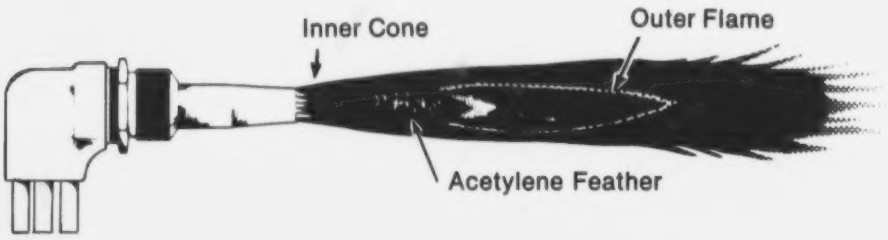
EXAMPLES: Containers that have held gases such as nitrogen, carbon dioxide, or argon

VII. Types of oxyacetylene cutting flames (Figures 4-6)

A. Carburizing flame

(NOTE: The flame illustrated has an excess of acetylene gas.)

FIGURE 4

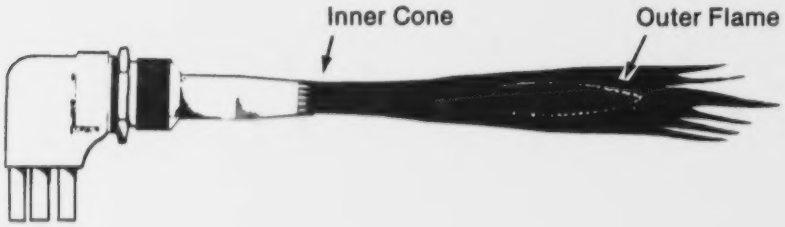


INFORMATION SHEET

B. Neutral flame

(NOTE: The flame illustrated has the proper ratio of oxygen to acetylene.)

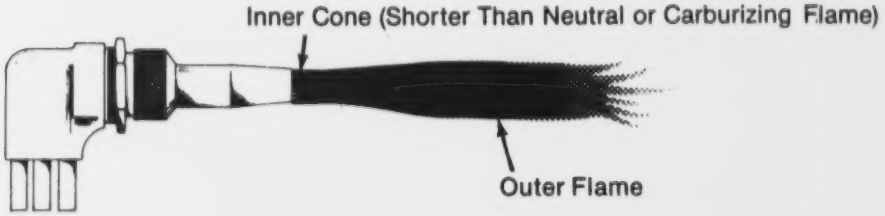
FIGURE 5



C. Oxidizing flame

(NOTE: The flame illustrated has an excess of oxygen.)

FIGURE 6



VIII. Differences between flashback and backfire

A. Flashback — Flame disappears inside torch body; at the same time, a squealing noise occurs and smoke and/or sparks are emitted from the torch tip

B. Backfire — Flame burns momentarily back into tip; then a loud snap or pop is emitted from the torch and the flame either goes out or continues to burn in a normal manner

IX. Steps to follow in case of flashback

A. Close oxygen preheat valve

B. Close oxygen torch valve

INFORMATION SHEET

C. Close acetylene torch valve

D. Release oxygen pressure-regulating screw

E. Release acetylene pressure-regulating screw

F. Examine acetylene unit

G. Reset regulator pressures

H. Light torch

(NOTE: If heavy smoke comes out of the torch tip and the torch body becomes hot, the flashback has probably traveled past the mixing chamber into the hose. In this case, shut off the oxygen and acetylene cylinder, and then notify the supervisor.)

X. Causes of backfire

(NOTE: The causes listed below should be carefully checked to control backfire.)

A. Not enough acetylene or oxygen pressure for the tip size used

B. Loose cutting tip

C. Dirty tip

(NOTE: Tip may have deposits or metal particles inside orifice. These deposits may overheat and act as ignitors.)

D. Overheating of cutting tip

E. Bad O-ring in torch body

XI. Common cutting-torch tips and their uses (Figure 7-17)

(NOTE: Most of the following cutting tips are available in two or more sizes and should be selected on the basis of the thickness of the metal to be cut and the job to be performed.)

A. Straight-line or circular cutting of clean plate

FIGURE 7

INFORMATION SHEET

B. Splitting angle iron, trimming plate, and cutting sheet metal

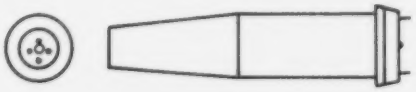
FIGURE 8

C. Hand cutting rivet heads; machine cutting 30-degree bevels

FIGURE 9

D. Straight-line or shape cutting of clean plate

FIGURE 10



E. Cutting rusty or painted surfaces

FIGURE 11

F. Cast-iron cutting and preparing welding Vs

FIGURE 12

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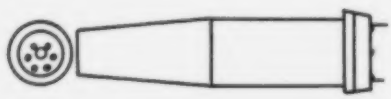
INFORMATION SHEET

G. General cutting; cutting cast iron and stainless steel

FIGURE 13

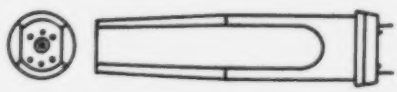


H. Grooving, flame machining, gouging, and removing imperfect welds

FIGURE 14

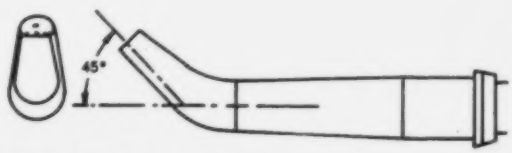
I. Grooving, gouging, or removing imperfect welds

FIGURE 15



J. Machine cutting 45-degree bevels or hand cutting rivet heads

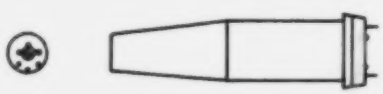
FIGURE 16



K. Removing rivet heads (washing)

(NOTE: Flared cutting orifices provide large oxygen stream of low velocity.)

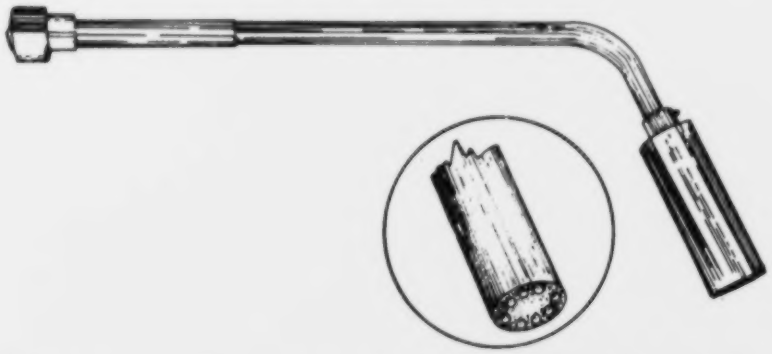
FIGURE 17



INFORMATION SHEET

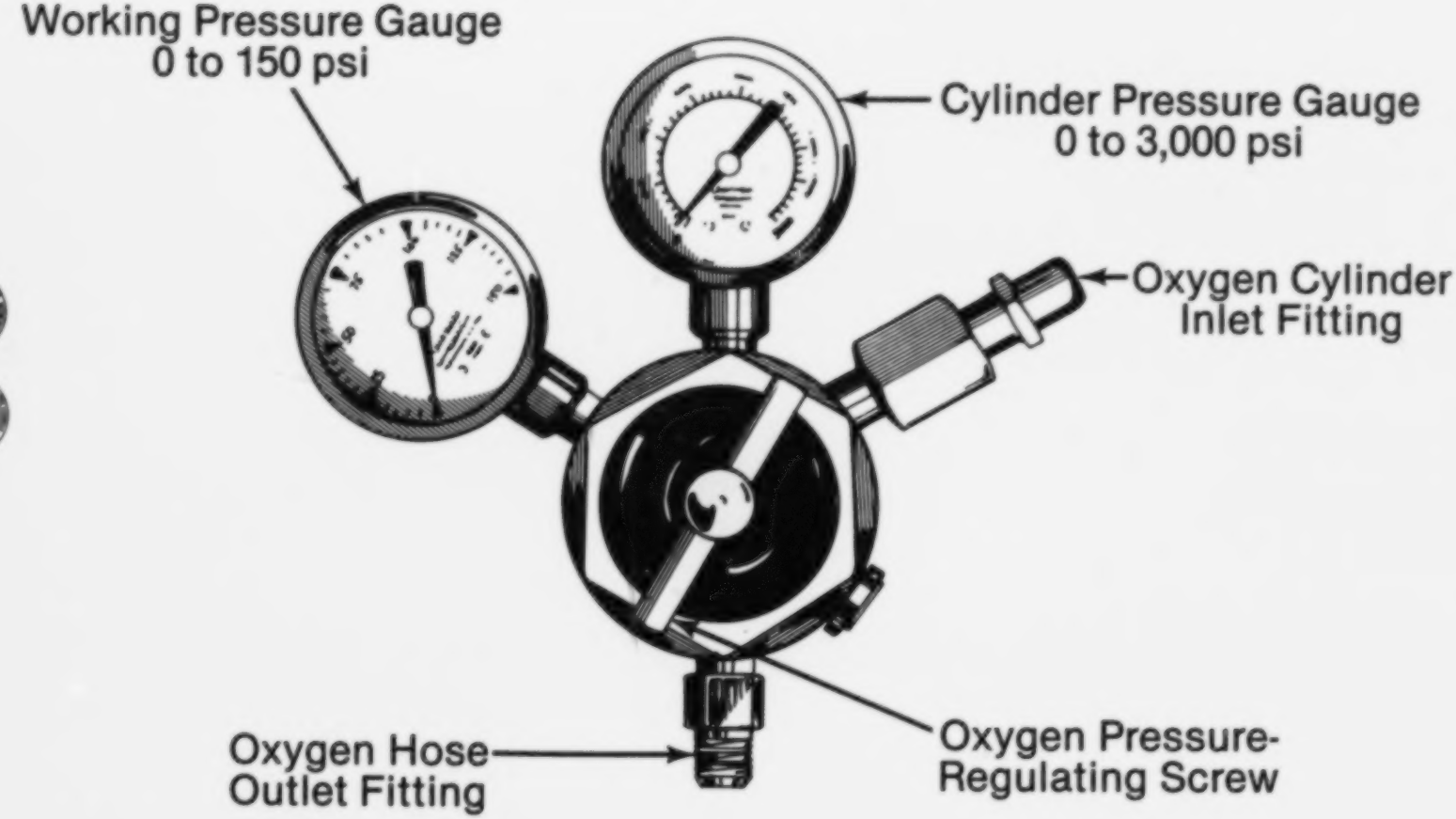
XII. Multiflame heating nozzle (rosebud) and tip (Figure 18)

FIGURE 18



XIII. Uses of a multiflame heating nozzle (rosebud) — Used to heat parts or metals, such as bearings, before fitting them to the journal; also used to preheat metal before welding

Oxygen Regulator Gauges



TM #1

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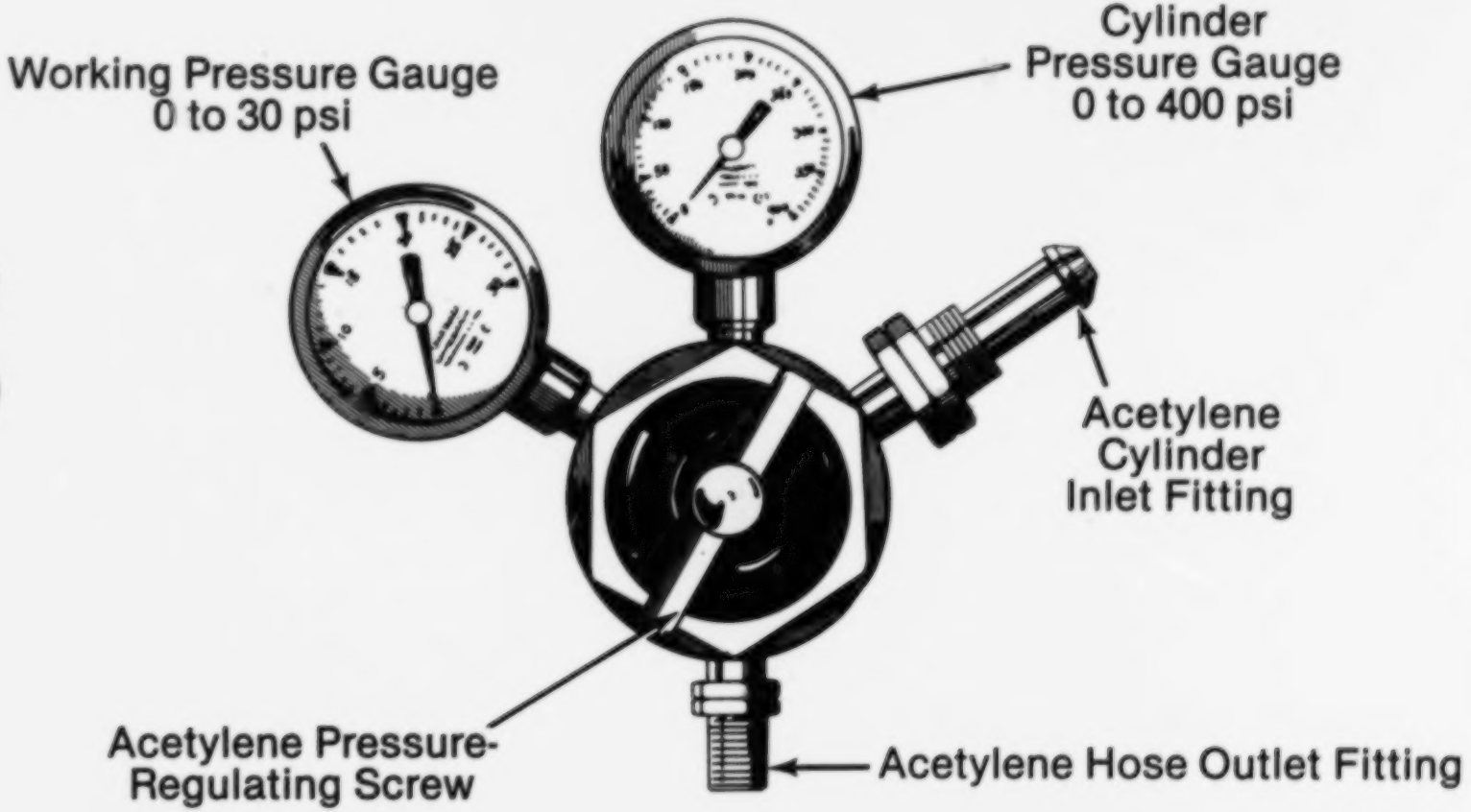
HEM - 145-G

Acetylene Regulator Gauges



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TM #2

HEM - 147-G

OXYACETYLENE CUTTING
UNIT II

JOB SHEET #1 — SET UP EQUIPMENT FOR OXYACETYLENE CUTTING

I. Equipment and materials

A. Oxygen cylinder

B. Acetylene cylinder

C. Oxygen regulator

D. Acetylene regulator

E. Hoses

F. Wrench

G. Cylinder truck

H. Foam or multipurpose dry-chemical fire extinguisher

I. Soapsuds

(NOTE: Ivory soap is recommended for making soapsuds.)

J. Clean paintbrush

K. Torch body with tips

L. Welding goggles

M. Coveralls or protective clothing free of oil and grease

II. Procedure

A. Fasten cylinders in a vertical position on cylinder truck

(CAUTION: To prevent damage to valves, never use acetylene from a cylinder that is not in a vertical position. Valve damage might cause cylinder to explode.)

B. Remove caps from cylinders

C. Crack valves of each cylinder to remove foreign material; close valves

JOB SHEET #1

D. Connect oxygen regulator to oxygen cylinder

(CAUTION: Do not use oil or any thread compound on any connections in the oxyacetylene system.)

1. Turn oxygen pressure-regulating screw counterclockwise until tension on spring is released

2. Slowly turn cylinder valve wide open

E. Connect acetylene regulator to acetylene cylinder

1. Turn acetylene pressure-regulating screw counterclockwise until tension on spring is released

2. Open cylinder valve one-half to three-quarters of a turn

(NOTE: Never open cylinder valve more than one and one-half turns. Leave wrench with cylinder.)

F. Connect acetylene hose to acetylene regulator; purge hose

G. Connect oxygen hose to oxygen regulator; purge hose

H. Connect torch body to oxygen and acetylene hoses

I. Close both valves on torch body

J. Attach cutting attachment to torch body

(NOTE: The tip size is determined by the thickness of metal to be cut and the manufacturer's instructions.)

K. Close oxygen preheat valve on cutting attachment

L. Turn oxygen pressure-regulating screw clockwise until working pressure is reached

M. Turn acetylene pressure-regulating screw clockwise until correct working pressure is reached

(CAUTION: At pressure higher than 15 psi, acetylene becomes unstable and highly explosive.)

N. Use soapsuds to test all connections for leaks

(NOTE: Apply soapsuds with a clean paintbrush.)

O. Close regulator valves

P. Proceed to Job Sheet #2

OXYACETYLENE CUTTING
UNIT II

JOB SHEET #2 — TURN ON, LIGHT, ADJUST TO A NEUTRAL FLAME, AND TURN OFF OXYACETYLENE CUTTING EQUIPMENT

I. Equipment and materials

A. Oxyacetylene cutting outfit with tip assembly

B. Wrench

C. Welding gloves

D. Welding goggles

E. Coveralls or protective clothing free of oil and grease

F. Flint lighter

G. Foam or multipurpose dry-chemical fire extinguisher

H. Tip cleaners

II. Procedure

A. Check all cylinder, regulator, and torch valves to make sure that they are closed

B. Open acetylene cylinder valve one-half to three-quarters of a turn

(CAUTION: Never open cylinder valve more than one and one-half turns.)

C. Open acetylene valve on torch one turn

D. Turn acetylene pressure-regulating screw clockwise until desired pressure is reached

(NOTE: Oxygen and acetylene pressures and size of tip depend upon the thickness of metal to be cut. Use pressures and tip size recommended by manufacturer.)

(CAUTION: Acetylene becomes unstable and highly explosive at pressures higher than 15 psi.)

E. Close acetylene valve on torch

F. Open oxygen cylinder valve all the way

G. Open oxygen torch valve all the way

JOB SHEET #2

H. Open oxygen preheat valve on cutting attachment one turn

I. Turn oxygen pressure-regulating screw clockwise until desired pressure is reached

J. Close oxygen preheat valve on cutting attachment

K. Open acetylene valve on torch one-quarter turn

L. Clean tip

(NOTE: Clean tip before lighting torch and as often as needed.)

M. Light torch with flint lighter and adjust until smoke on flame clears

N. Open oxygen preheat valve slowly and adjust to a neutral flame

O. Depress oxygen cutting lever, and check to see that a neutral flame is present

(NOTE: If necessary, adjust the oxygen preheat valve with the oxygen cutting lever depressed until a neutral flame is secured. Pressure rises slightly when valve is closed.)

P. Close acetylene valve on torch

Q. Close acetylene cylinder valve

R. Close oxygen preheat valve

S. Close oxygen cylinder valve

T. Open acetylene valve on torch

(NOTE: When gauges reach zero, close torch valve and release acetylene pressure-regulating screw by turning counterclockwise.)

U. Open oxygen preheat valve on torch

(NOTE: When gauges reach zero, close oxygen preheat valve and turn oxygen pressure-regulating screw counterclockwise.)

V. Close oxygen valve on torch

W. Place torch and hose on hanger or brackets provided

(NOTE: If regulators are removed from cylinders, replace the caps.)

X. Clean work area; clean and put away all tools and equipment

OXYACETYLENE CUTTING
UNIT II

JOB SHEET #3 — CUT MILD STEEL AT A 90-DEGREE ANGLE, STOP, AND RESTART THE CUT

I. Equipment and materials

- A. Oxyacetylene cutting outfit with tip assembly
- B. Mild steel plate, approximately 1/4" x 4" x 8"
- C. Soapstone with a sharp point or edge
- D. Straightedge
- E. Welding gloves
- F. Welding goggles
- G. Pliers
- H. Coveralls or protective clothing free of oil and grease
- I. Flint lighter
- J. Welding or cutting table
- K. Slag box
- L. Can of water
- M. Cutting tip
- N. Foam or multipurpose dry-chemical fire extinguisher
- O. Tip cleaners

II. Procedure

(NOTE: Follow procedure in Job Sheet #2, steps A through O, to turn on equipment.)

- A. Make a 90-degree cut
  1. Mark four parallel lines 2 inches apart on plate to be cut
  2. Adjust oxygen regulator

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JOB SHEET #3

3. Adjust acetylene regulator

4. Place plate to be cut over slag box

5. Clean tip

   (NOTE: Clean tip before lighting torch and as often as needed.)

6. Light torch with flint lighter

7. Adjust to neutral flame

8. Place hoses behind you

9. Assume comfortable position

10. Maneuver torch as required

    (NOTE: Sometimes you must use both hands to hold torch steady for a straight cut.)

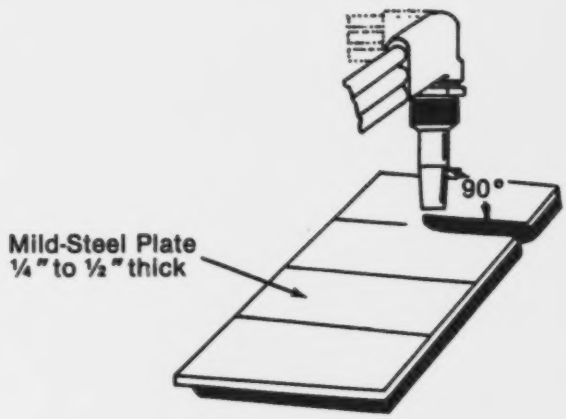
11. Hold preheat flame with tip of inner cone 1/16 to 1/8 inch above top of plate at right edge until red spot appears

    (CAUTION: Burning metal flames and sometimes sparks, creating the danger of burns.)

12. Depress oxygen cutting lever and move from right to left across the plate (Figure 19)

    (NOTE: Left-handed operators move from left to right.)

FIGURE 19



JOB SHEET #3

13. Hold tip at right angle to work, while cutting with inner cone approximately 1/16 inch above work

14. Make 90-degree cuts until you have developed the proper procedure

15. Cool metal by placing in can of water with the aid of pliers

B. Restart a cut

1. Release oxygen cutting lever

2. Preheat only the edge where cutting action was stopped

3. Depress oxygen cutting lever slowly and continue cut

(NOTE: Follow procedure in Job Sheet #2, steps P through W, to turn off equipment.)

C. Clean work area; clean and put away all tools and equipment

OXYACETYLENE CUTTING
UNIT II

JOB SHEET #4 — CUT ROUND STOCK

I. Equipment and materials

A. Oxyacetylene cutting outfit with tip assembly

B. Pieces of reinforcing bar, 1/2-inch, 5/8-inch, 3/4-inch, or 1-inch

C. Soapstone with sharp point or edge

D. Tape

E. Welding gloves

F. Welding goggles

G. Pliers

H. Coveralls or protective clothing free from oil and grease

I. Flint lighter

J. Welding or cutting table

K. Slag box

L. Can of water

M. Cutting tip

N. Foam or multipurpose dry-chemical fire extinguisher

O. Tip cleaners

II. Procedure

(NOTE: Follow procedure in Job Sheet #2, steps A through O, to turn on equipment.)

A. Mark reinforcing bar at desired length

B. Adjust oxygen and acetylene regulators

C. Place area to be cut over slag box

D. Clean tip

JOB SHEET #4

(NOTE: Clean tip before lighting torch and as often as needed.)

E. Light torch with flint lighter

F. Adjust to neutral flame

G. Place hoses behind you

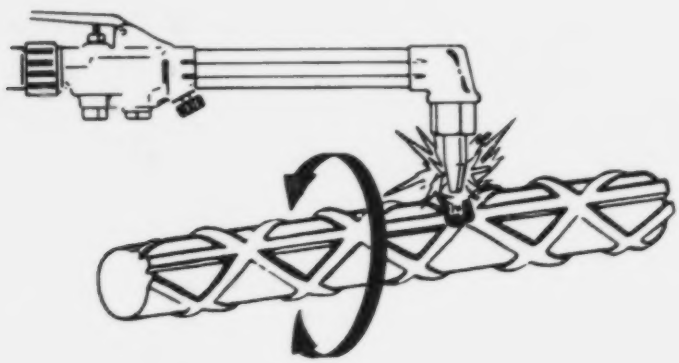
H. Assume comfortable position

I. Maneuver torch as required

J. Hold preheat flame with tip of inner cone 1/16 to 1/8 inch above edge of reinforcing bar until it becomes red

K. Depress cutting lever, and rotate torch in direction of travel until rod is cut (Figure 20)

FIGURE 20



L. Hold tip at right angle to work, while cutting with inner cone approximately 1/16 inch above work

M. Cool metal by placing in can of water with the aid of pliers

N. Repeat procedure for each bar or rod

(NOTE: Follow procedure in Job Sheet #2, steps P through W, to turn off equipment.)

O. Clean work area; clean and put away all tools and equipment

OXYACETYLENE CUTTING
UNIT II

JOB SHEET #5 — CUT CABLE

I. Equipment and materials

A. Oxyacetylene cutting outfit with tip assembly

B. Cutting tip

C. Flint lighter

D. Piece of cable

E. Soapstone with sharp point or edge

F. Welding goggles

G. Welding gloves

H. Can of water

I. Foam or multipurpose dry-chemical fire extinguisher

J. Coveralls or protective clothing free from oil and grease

K. Tip cleaners

II. Procedure

(NOTE: Follow procedure in Job Sheet #2, steps A through O, to turn on equipment.)

A. Place fire extinguisher near work area

B. Determine where cable is to be cut; mark with soapstone

C. Adjust oxygen and acetylene regulators

D. Clean tip

(NOTE: Clean tip before lighting torch and as often as needed.)

E. Light torch with flint lighter

F. Adjust to neutral flame

G. Place hoses behind you

JOB SHEET #5

H. Assume comfortable position

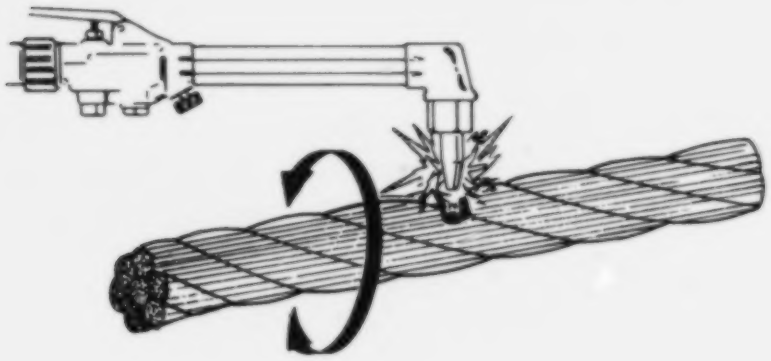
I. Maneuver torch as required

(CAUTION: If there is tension on the cable, take care to avoid flying loose ends when the cable is cut. These ends can be very dangerous.)

J. Hold preheat flame with tip of inner cone 1/16 to 1/8 inch above edge of cable until it becomes red

K. Depress cutting lever, and rotate torch tip in direction of travel until cable is cut (Figure 21)

FIGURE 21



L. Hold tip at right angle to work, while cutting with inner cone approximately 1/16 inch above work

M. Cool metal by pouring water over hot ends

N. Repeat procedure for each cut

(NOTE: This is a very good method to use on all types of cables as it is quick and easy and will weld the ends, thus reducing strain on the seizing and preventing raveling. Follow procedure in Job Sheet #2, steps 0 through W, to turn off equipment.)

O. Clean work area; clean and put away all tools and equipment

OXYACETYLENE CUTTING
UNIT II

TEST

NAME _____ SCORE _____

1. Match terms associated with oxyacetylene cutting to their correct definitions. Write the correct numbers in the blanks.

_____a.	Colorless, gaseous hydrocarbon used in cutting and welding	1. Toxic
_____b.	Element that is normally a colorless, odorless, and tasteless gas; used in combination with other substances in cutting and welding	2. Purge
_____c.	Flame cutting of metal in which the preheating of the metal is accomplished with a flame produced by an oxyacetylene torch	3. Oxygen
_____d.	To remove any foreign material from a system or component by flushing with the gas used in that system	4. Combustible
_____e.	Pounds per square inch	5. Oxyacetylene cutting
_____f.	Capable of burning	6. psi
_____g.	Poisonous	7. Acetylene
_____h.	That part of a shaft, axle, or spindle that turns in a bearing	8. Seizing
_____i.	Striker used to ignite torch	9. Flint lighter
_____j.	Metal container with a layer of water or sand to catch hot material	10. Journal
_____k.	Metal that melts away during the oxyacetylene cutting process	11. Slag box
_____l.	Firmly binding cable with soft iron wire	12. Slag

2. State color codes for oxygen and acetylene.

   a. Oxygen — _____

   b. Acetylene — _____

TEST

3. Arrange in order stages in the oxyacetylene cutting process. Write a "1" before the first step, a "2" before the second step, and so on.

_____a. Mixture burns at several orifices (preheat orifices) in torch tip

_____b. Oxygen jet quickly oxidizes the heated base metal and blows it away

_____c. Separate, flexible hoses carry gases to torch

_____d. Flame heats base metal to a dull, cherry red

_____e. Pressure-regulated acetylene and pressure-regulated compressed oxygen are supplied from two cylinders

_____f. Removal of material leaves a cut in the metal

_____g. Operator ignites acetylene gas with spark from flint lighter

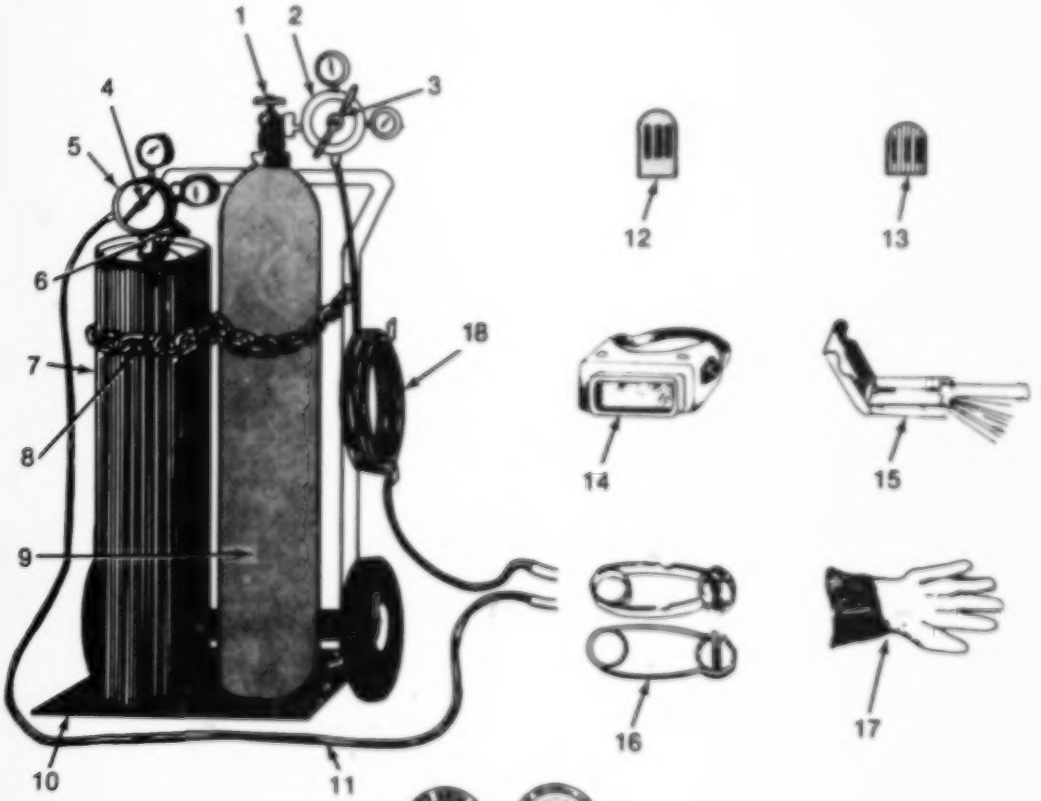
_____h. Operator presses oxygen lever, and jet of oxygen rushes out of cutting orifice

_____i. Operator opens oxygen torch valve, and gases are mixed inside torch

TEST

4. Identify the parts of an oxyacetylene cutting outfit. Write the correct numbers in the blanks.

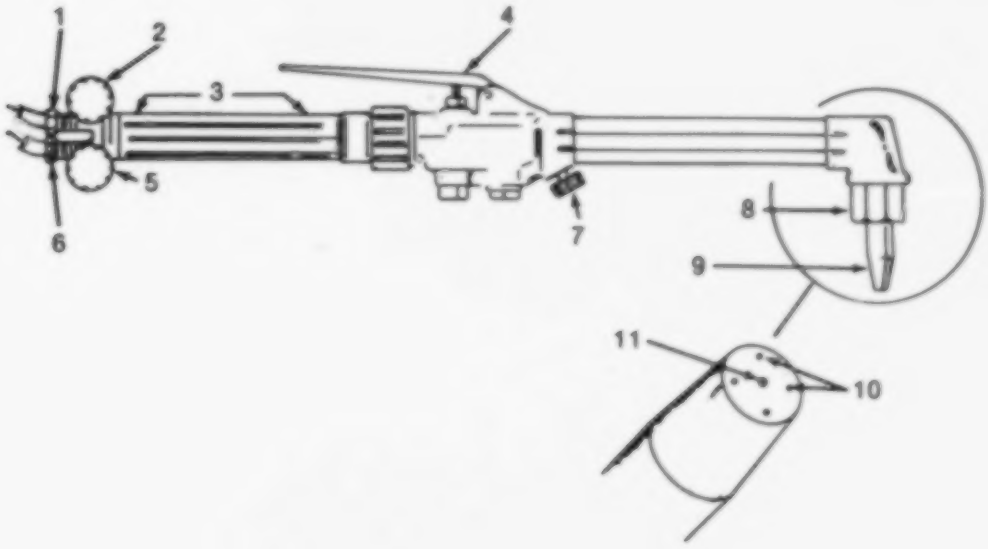
_____a.	Oxygen hose	_____j.	Flint lighters
_____b.	Oxygen cylinder valve	_____k.	Oxygen cylinder cap
_____c.	Acetylene cylinder	_____l.	Safety chain
_____d.	Acetylene cylinder cap	_____m.	Welding goggles
_____e.	Welding gloves	_____n.	Acetylene cylinder valve
_____f.	Oxygen cylinder	_____o.	Oxygen pressure-regulating screw
_____g.	Acetylene hose	_____p.	Tip cleaners
_____h.	Acetylene regulator	_____q.	Oxygen regulator
_____i.	Acetylene pressure-regulating screw	_____r.	Cylinder truck



TEST

5. Identify the parts of a torch body and cutting attachment. Write the correct numbers in the blanks.

_____a.	Acetylene fitting (grooved nut, left-hand threads)	_____f.	Preheat orifices
_____b.	Cutting orifice	_____g.	Oxygen torch valve
_____c.	Oxygen fitting (right-hand threads)	_____h.	Tip
_____d.	Tip nut	_____i.	Oxygen cutting lever
_____e.	Oxygen preheat valve	_____k.	Torch body
		_____k.	Acetylene torch valve



6. State twelve safety rules for working with oxyacetylene equipment.

a. _____

b. _____

c. _____

d. _____

TEST

e. _____

f. _____

g. _____

h. _____

i. _____

j. _____

k. _____

l. _____

7. Identify the following types of oxyacetylene cutting flames. Write the correct names in the blanks.

Neutral flame **Oxidizing flame** **Carburizing flame**

a. _____

b. _____

c. _____

TEST

8. Distinguish between flashback and backfire. Write an "F" in the blank before flashback and a "B" in the blank before backfire.

_____a. Flame burns momentarily back into tip; then a loud snap or pop is emitted from the torch and the flame either goes out or continues to burn in a normal manner

_____b. Flame disappears inside torch body; at the same time, a squealing noise occurs and smoke and/or sparks are emitted from the torch tip

9. Arrange in order steps to follow in case of flashback. Write a "1" before the first step, a "2" before the second step, and so on.

_____a. Light torch

_____b. Release oxygen pressure-regulating screw

_____c. Reset regulator pressures

_____d. Close oxygen torch valve

_____e. Close oxygen preheat valve

_____f. Release acetylene pressure-regulating screw

_____g. Close acetylene torch valve

_____h. Examine acetylene unit

10. Select from the following list causes of backfire. Write an "X" in the blank before each correct answer.

_____a. Too much oxygen

_____b. Not enough acetylene or oxygen pressure for the tip size used

_____c. Too much acetylene

_____d. Loose cutting tip

_____e. Overheating of cutting tip

_____f. Bad O-ring in torch body

_____g. Dirty tip

TEST

11. Match common cutting-torch tips to their correct uses. Write the correct numbers in the blanks.

_____a. Machine cutting 45-degree bevels or hand cutting rivet heads

_____b. Cast-iron cutting and preparing welding Vs

_____c. Splitting angle iron, trimming plate, and cutting sheet metal

_____d. General cutting; cutting cast iron and stainless steel

_____e. Grooving, gouging, or removing imperfect welds

_____f. Hand cutting rivet heads; machine cutting 30-degree bevels

_____g. Straight-line or circular cutting of clean plate

_____h. Cutting rusty or painted surfaces

_____i. Grooving, flame machining, gouging, and removing imperfect welds

_____j. Removing rivet heads (washing)

_____k. Straight-line or shape cutting of clean plate

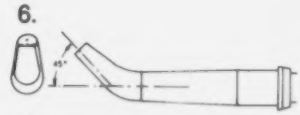
1.

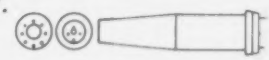
2.

3.

4.

5.

6. 

7. 

8.

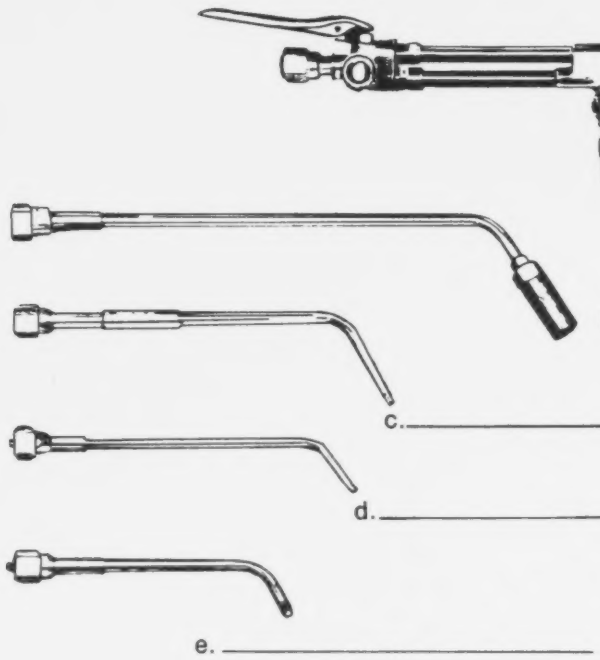
9.

10.

11.

TEST

12. Identify a multiflame heating nozzle (rosebud) and tip from the illustrations below. Write an "X" in the blank beside the correct illustration.



a. _____

b. _____

c. _____

d. _____

e. _____

13. Describe uses of a multiflame heating nozzle (rosebud).

_____

_____

_____

(NOTE: Test question 14 lists the job sheets. They are an important part of this test. If they have not been completed, check with your instructor.)

14. Demonstrate the ability to

a. Set up equipment for oxyacetylene cutting.

b. Turn on, light, adjust to a neutral flame, and turn off oxyacetylene cutting equipment.

c. Cut mild steel at a 90-degree angle, stop, and restart the cut.

d. Cut round stock.

e. Cut cable.

OXYACETYLENE CUTTING
UNIT II

ANSWERS TO TEST

1.	a.	7	d.	2	g.	1	j.	11
	b.	3	e.	6	h.	10	k.	12
	c.	5	f.	4	i.	9	l.	8

2. a. Green

   b. Red

3.	a.	5	d.	6	g.	3		
	b.	8	e.	1	h.	7		
	c.	2	f.	9	i.	4		

4.	a.	18	f.	9	k.	12	p.	15
	b.	1	g.	11	l.	8	q.	2
	c.	7	h.	5	m.	14	r.	10
	d.	13	i.	4	n.	6		
	e.	17	j.	16	o.	3		

5.	a.	6	e.	7	i.	4		
	b.	11	f.	10	j.	3		
	c.	1	g.	2	k.	5		
	d.	8	h.	9				

6. Answer should include any twelve of the following

   a. Make sure that either a foam or a multipurpose dry-chemical fire extinguisher is readily available and in working condition

   b. Wear welding goggles, gloves, and protective clothing

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ANSWERS TO TEST

c. Wear gloves to handle hot metal

d. Use open torch only in a well-ventilated place

e. Avoid breathing toxic fumes

f. Do not leave a burning torch unattended

g. Secure cylinders in a safe place

h. Cut or weld at least 5 feet from cylinders

i. Always use regulators; do not use oxygen or acetylene directly from cylinders

j. Use flint lighters, *not matches,* for lighting torch

k. Use hoses designated for oxygen and acetylene only

l. Do not use oil on regulators, torches, fittings, or any equipment surface that may come in contact with oxygen

m. Do not use compressed oxygen to clean off clothing

n. Do not breathe compressed oxygen directly from cylinder or hose

o. Use soapsuds and paintbrush to test connections for leaks

p. Do not use acetylene at pressures higher than 15 pounds per square inch

q. Do not cut or weld directly on gravel or concrete

r. Keep heat, flames, and sparks away from combustibles

s. Do not cut or weld on containers that have been used to store combustible materials unless containers have been properly cleaned and purged

7. a. Oxidizing flame

b. Carburizing flame

c. Neutral flame

ANSWERS TO TEST

8. a. B
   b. F

9. a. 8 e. 1
   b. 4 f. 5
   c. 7 g. 3
   d. 2 h. 6

10. b, d, e, f, g

11. a. 6 e. 4 i. 10
    b. 1 f. 8 j. 2
    c. 5 g. 3 k. 11
    d. 9 h. 7

12. b

13. Description should include the following — Used to heat parts or metals, such as bearings, before fitting them to the journal; also used to preheat metal before welding

14. Performance skills evaluated to the satisfaction of the instructor

OXYACETYLENE BRAZE WELDING
UNIT III

UNIT OBJECTIVE

After completing this unit, the student should be able to perform several different types of braze welds. The student will show this knowledge by completing the job sheets and unit test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match to their correct definitions terms associated with oxyacetylene braze welding.
2. Identify oxyacetylene welding equipment.
3. Name factors that determine selection of welding tip size.
4. Distinguish between braze welding and fusion welding.
5. Distinguish between advantages and disadvantages of braze welding.
6. State the importance of having a chemically clean metal surface in braze welding.
7. State methods of removing oxides from a clean metal surface.
8. Distinguish among characteristics of oxyacetylene welding flames.
9. Select from a list purposes of flux.
10. Describe reactions of molten bronze at different base metal temperatures.
11. Demonstrate the ability to
    a. Braze weld a square-groove butt joint.
    b. Braze weld a lap joint.
    c. Braze weld a tee or fillet joint.

OXYACETYLENE BRAZE WELDING
UNIT III

SUGGESTED ACTIVITIES

I. Suggested activities

A. Gather equipment and materials for job sheet demonstrations.

B. Check with manufacturers and distributors for visual aids to demonstrate welding procedures.

C. Obtain transparencies.

(NOTE: Transparencies are available from AGC and CIMC.)

D. Provide students with objective sheet.

E. Discuss unit and specific objectives.

F. Provide students with information and job sheets.

G. Discuss information sheet.

H. Demonstrate and discuss procedures outlined in job sheets.

I. Give test.

J. Complete appropriate section of competency profiles.

(NOTE: Competency profiles are available from AGC and CIMC.)

II. Instructional materials

A. Objective sheet

B. Suggested activities

C. Information sheet

D. Transparency masters

1. TM #1 — Braze Welding a Butt Joint
2. TM #2 — Oxyacetylene Welding Equipment
3. TM #3 — Welding Torches
4. TM #4 — Oxygen Regulator Gauges
5. TM #5 — Acetylene Regulator Gauges

SUGGESTED ACTIVITIES

E. Job sheets

1. Job Sheet #1 — Braze Weld a Square-Groove Butt Joint

2. Job Sheet #2 — Braze Weld a Lap Joint

3. Job Sheet #3 — Braze Weld a Tee or Fillet Joint

F. Test

G. Answers to test

III. Unit references

A. Cowan, Earl, Clifton Braker, and Wayman Penner. *Welding*. Stillwater, Oklahoma: State Department of Vocational and Technical Education/Curriculum and Instructional Materials Center, Revised 1974.

B. Foutes, William. *Diesel Mechanics; Fundamentals*. Stillwater, Oklahoma: Mid-America Vocational Curriculum Consortium, Inc., 1982.

C. Hendrix, Laborn J. "Bud." *Millwright Instructional Materials*. Stillwater, Oklahoma: State Department of Vocational and Technical Education/Curriculum and Instructional Materials Center and The Associated General Contractors of America, 1980.

D. Smith, Eddie. *Agricultural Mechanics*. Stillwater, Oklahoma: State Department of Vocational and Technical Education/Curriculum and Instructional Materials Center, 1977.

OXYACETYLENE BRAZE WELDING
UNIT III

INFORMATION SHEET

I. Terms and definitions

A. Alloy rod — Rod that has a mixture of metallic properties; composed of two or more elements of which one is a metal

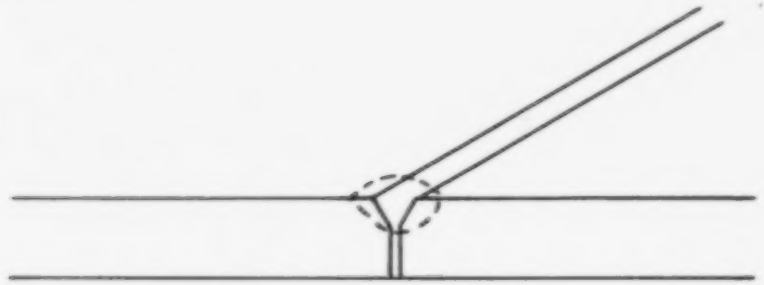
B. Base metal — Metal to be welded

C. Braze welding — Heating base metal to a dull red color and depositing a bead over the seam (joint) with a filler rod, without melting the base metal (Transparency #1)

D. Butt joint — Weld between two metal joints on the same plane (Figure 1)

EXAMPLE:

FIGURE 1



E. Ductile — Capable of being drawn or stretched

F. Filler rod — Bronze rod with characteristics similar to base metal

G. Flux — Chemical used to clean metals and to promote fusion and adhesion during welding process

H. Fusion — Process of liquefying by melting

I. Fusion welding — Joining pieces of metal by heating adjoining edges to the fusion point and allowing them to flow or run together and then cool

J. Malleability — Property of metals that allows them to be bent or permanently distorted without rupture

INFORMATION SHEET

K. Molten — Liquefied by heat

L. Oxide — Substance produced when oxygen is combined with an element

EXAMPLES: Rust, corrosion, coating film, scale

M. Oxidizing — Combining oxygen with another substance

EXAMPLE: Metal is oxidized when the metal is cut.

N. Penetration — Distance from original surface of base metal to that point at which fusion ceases

O. Tack weld — Short weld used for temporarily holding material in place

P. Tinning operation — Process of melting a small amount of bronze rod onto surface of base metal and allowing it to spread along entire seam (joint)

(NOTE: It is this flow of the thin film of bronze that is known as *tinning*.)

II. Oxyacetylene welding equipment (Transparencies #2-#5)

A. Acetylene cylinder

B. Acetylene cylinder valve

C. Acetylene fitting (hex-grooved nut, left-hand threads)

D. Acetylene regulator

E. Oxygen cylinder

F. Oxygen cylinder valve

G. Oxygen fitting (right-hand threads)

H. Oxygen regulator

I. Torch body

J. Oxygen torch valve

K. Acetylene torch valve

L. Welding tip

M. Cylinder truck

INFORMATION SHEET

N. Safety chain

O. Welding goggles

P. Flint lighter

Q. Welding gloves

III. Factors that determine selection of welding tip size

A. Thickness of base metal

B. Size of welding rod

(NOTE: Follow manufacturer's recommendations when selecting tip size.)

IV. Differences between braze welding and fusion welding

A. Braze welding

1. Base metal is not melted

(NOTE: Base metal is heated only to a dull red color.)

2. Bronze rod is used to lay a thin coat of bronze along seam

B. Fusion welding

1. Base metal is melted and joined

2. Rod with characteristics similar to base metal is melted to join with melted base metal

V. Advantages and disadvantages of braze welding as compared to fusion welding

A. Advantages

1. Because it is not heated to a molten condition, provides less chance of destroying main characteristics of base metal

2. Uses less gas

3. Can be used to weld thin metals

4. Can be used to weld malleable castings

5. Increases speed of joining metals

6. May be used to join different kinds of metals

INFORMATION SHEET

B. Disadvantages

1. Cannot be used on metal where stress is a factor
2. Bronze rod is expensive to use
3. Is not recommended for parts that are raised to temperatures higher than melting point of bronze, either in service or during heat treatment

   (NOTE: The melting point of bronze is 1125°F to 1760°F.)
4. Bronze loses its strength at temperatures above 500°F
5. Will not bond unless base metal has corrosion-resistant properties similar to bronze

VI. Importance of having a chemically clean metal surface in braze welding

A. Ensures that the molten bronze will adhere to base metal

B. Allows weld to form stronger bond on base metal

C. Allows bronze to flow smoothly and evenly over entire weld area

VII. Methods of removing oxides from a clean metal surface

(NOTE: Both methods should be used to completely remove oxides.)

A. Mechanical means

EXAMPLES: Wire brush, grinder

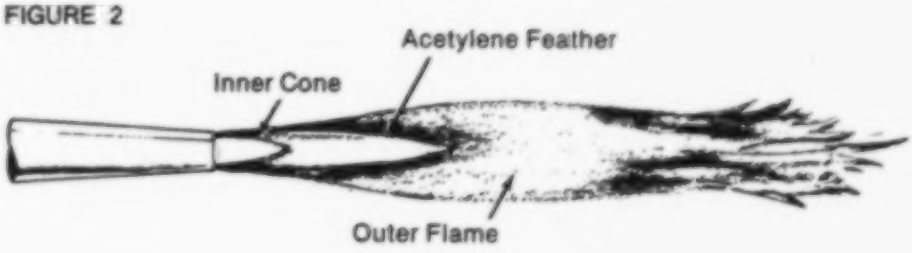
B. Chemical flux

VIII. Characteristics of types of oxyacetylene welding flames

A. Carburizing flame (Figure 2)

EXAMPLE:

FIGURE 2



INFORMATION SHEET

1. Burns excess of acetylene

   (NOTE: An acetylene feather is visible on the inner cone.)

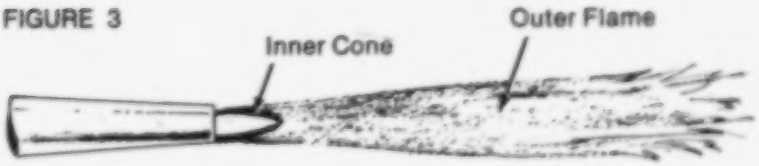
2. Is recommended for cutting cast iron

3. Introduces carbon into weld, causing hardening of the metal, which weakens weld

B. Neutral flame (Figure 3)

EXAMPLE:

FIGURE 3



1. Burns equal amounts of oxygen and acetylene
2. Is identified by clear, well-defined white cone
3. Reaches temperature of 5,950°F

C. Oxidizing flame (Figure 4)

EXAMPLE:

FIGURE 4

1. Burns excess of oxygen
2. Is identified by short, white inner cone
3. Oxidizes the metal, causing it to harden and become brittle
4. Is hottest flame
5. Is recommended for brazing

INFORMATION SHEET

IX. Purposes of flux

A. Cleaning base metal

B. Preventing oxidation of filler metal

C. Floating and removing oxides already present

D. Increasing flow of filler metal

E. Increasing ability of filler metal to adhere to base metal

F. Bringing filler metal into immediate contact with metals being joined

G. Permitting filler metal to penetrate pores of base metal

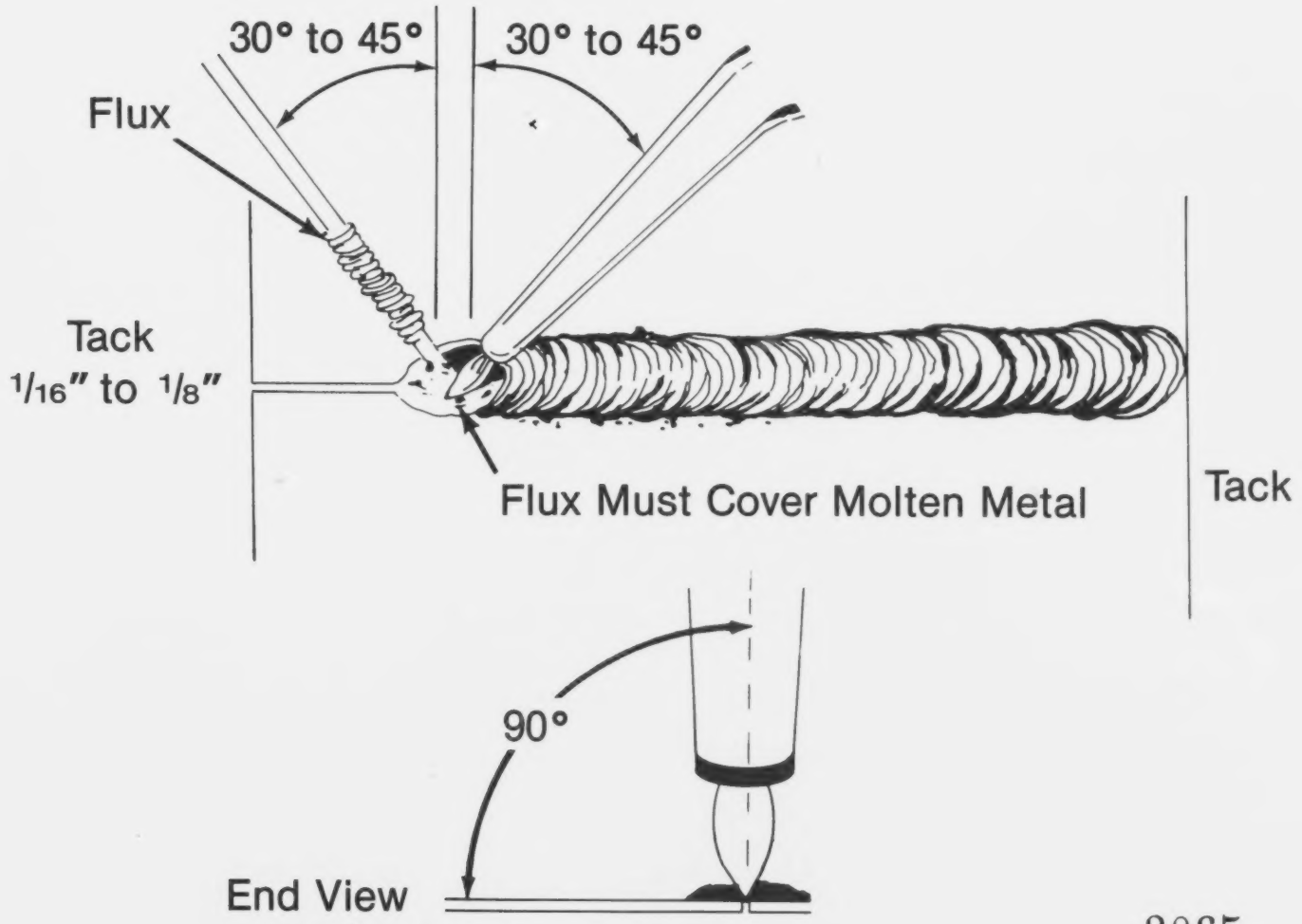
X. Reactions of molten bronze at different base metal temperatures

A. Too hot — Tends to boil and form little balls

B. Too cold — Forms into drops rather than flowing evenly over surface

C. Correct — Spreads evenly and flows over a considerable area

Braze Welding a Butt Joint



TM #1

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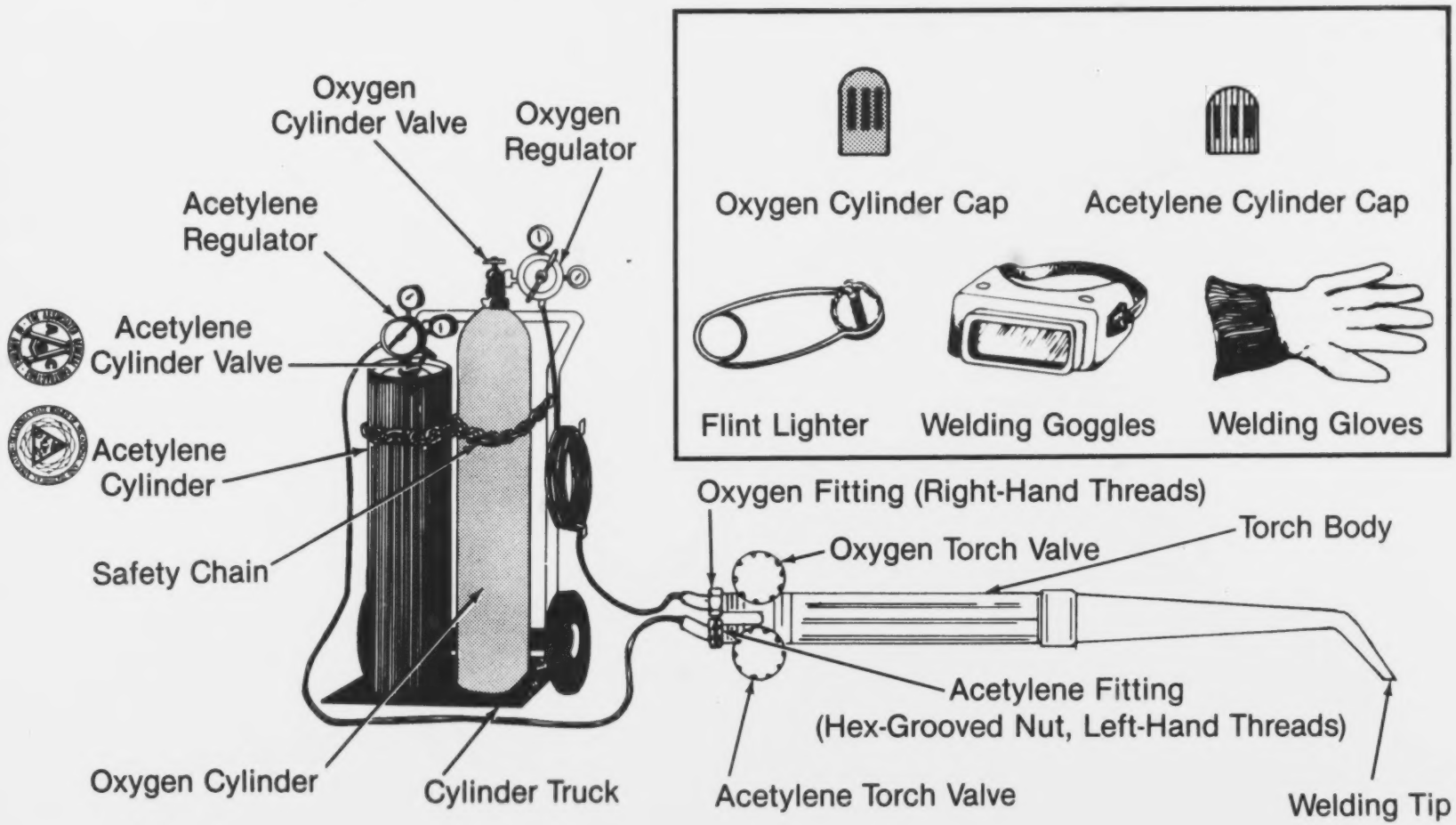
HEM - 183-G

Oxyacetylene Welding Equipment



TM #2

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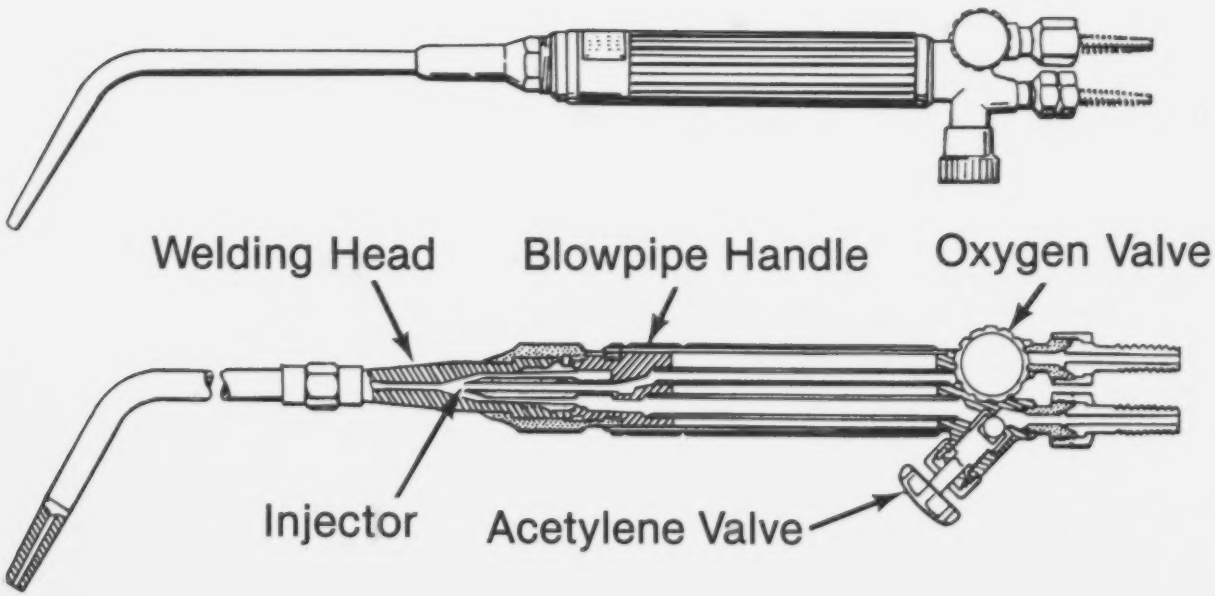
HEM - 185-G

Welding Torches



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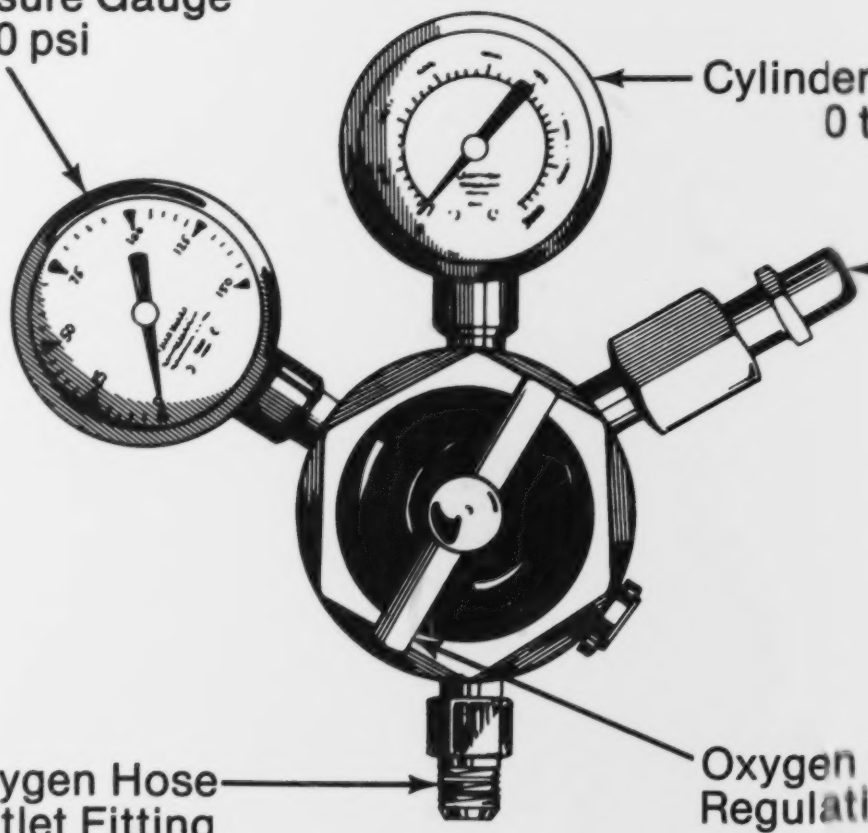
TM #3

HEM - 187-G

Oxygen Regulator Gauges



TM #4

2070

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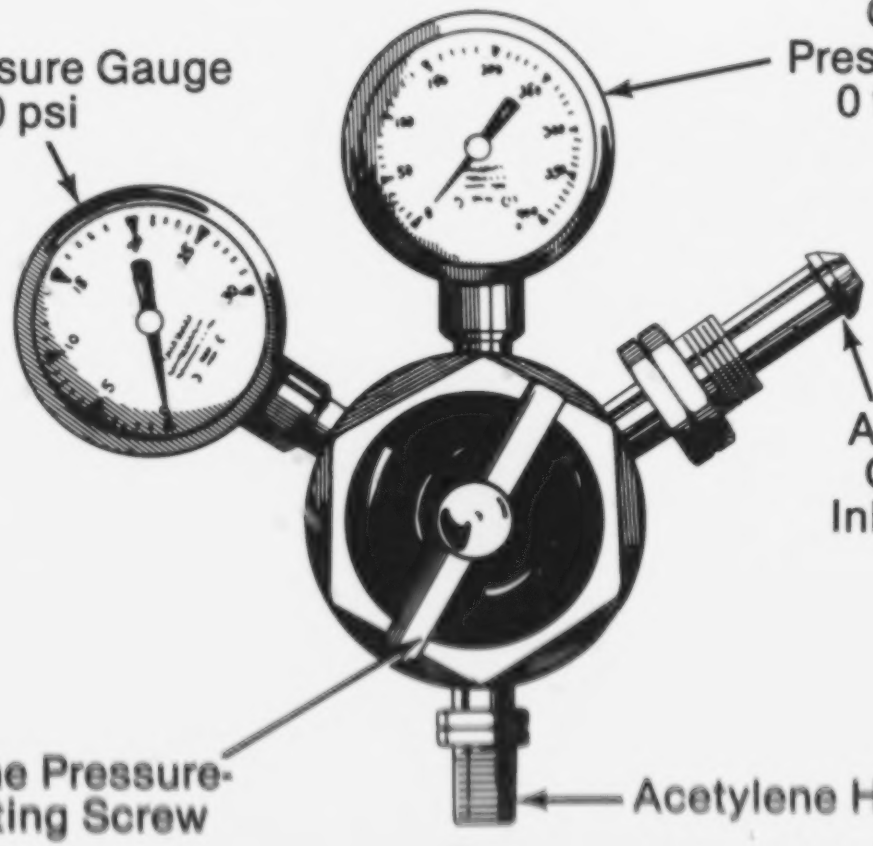
HEM - 1805

Acetylene Regulator Gauges



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OXYACETYLENE BRAZE WELDING
UNIT III

JOB SHEET #1 — BRAZE WELD A SQUARE-GROOVE BUTT JOINT

I. Equipment and materials

A. Oxyacetylene welding unit

B. Gloves

C. Safety glasses

D. Welding goggles

E. Manufacturer's recommended welding tip

F. Wire brush

G. Flint lighter

H. 2 firebricks

I. 2 strips mild steel, 1 ¼" x 6" x ⅛"

J. Manufacturer's recommended bronze filler rod

K. Welding flux

L. Service manual for oxyacetylene welding unit

II. Procedure

(NOTE: Be sure to follow shop safety regulations at all times.)

A. Clean metal

B. Place metal on firebricks

(NOTE: Arrange metal so that weld will be made in space between firebricks.)

C. Place metal strips in brazing position, 1/16 to ⅛ inch apart

D. Turn on oxyacetylene unit

E. Adjust working pressure of oxygen and acetylene to that recommended by manufacturer

F. Light torch and adjust to a neutral or slightly oxidizing flame

JOB SHEET #1

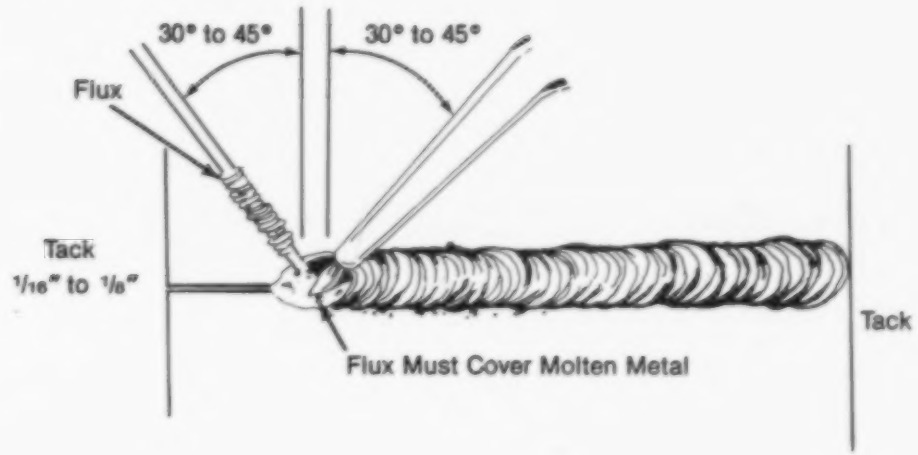
G. Preheat end of brazing rod and dip into flux, or use fluxed rod

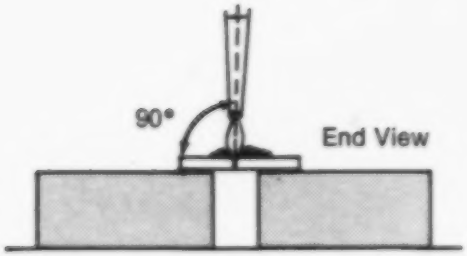
H. Tack metal in place using braze filler metal

I. Slightly heat surface of weld area

J. Hold torch at a 30- to 45-degree vertical angle; hold filler rod at same angle in opposite direction (Figure 5)

FIGURE 5





K. Melt a small amount of bronze rod onto surface; allow it to spread along entire seam when a cherry red color occurs

L. Start depositing proper size bead when base metal is tinned sufficiently

(NOTE: When metal is not hot enough, the bronze will form into drops; when metal is too hot, bronze tends to boil.)

JOB SHEET #1

M. Complete weld and show to instructor for evaluation

N. Clean work area; clean and put away all tools and equipment

OXYACETYLENE BRAZE WELDING
UNIT III

JOB SHEET #2 — BRAZE WELD A LAP JOINT

I. Equipment and materials

- A. Oxyacetylene welding unit
- B. Gloves
- C. Safety glasses
- D. Welding goggles
- E. Manufacturer's recommended welding tip, or #5
- F. Wire brush
- G. Flint lighter
- H. 2 firebricks
- I. 2 strips mild steel 1 ¼" × 6" × ⅛"
- J. Manufacturer's recommended bronze filler rod
- K. Welding flux
- L. Service manual for oxyacetylene welding unit

II. Procedure

(NOTE: Be sure to follow shop safety regulations at all times.)

- A. Clean metal
- B. Place metal on firebricks
- C. Place metal in brazing position, each strip overlapping the other ½ inch
- D. Turn on oxyacetylene unit
- E. Adjust working pressure of oxygen and acetylene to 5 pounds

  (NOTE: Follow manufacturer's recommendations.)
- F. Light torch and adjust to a neutral or slightly oxidizing flame
- G. Preheat end of brazing rod and dip into flux, or use fluxed rod
- H. Tack metal in place using braze filler metal
- I. Preheat joint at right end; weld to left

JOB SHEET #2

J. Hold torch and filler rod as shown in Figures 6 and 7

FIGURE 6

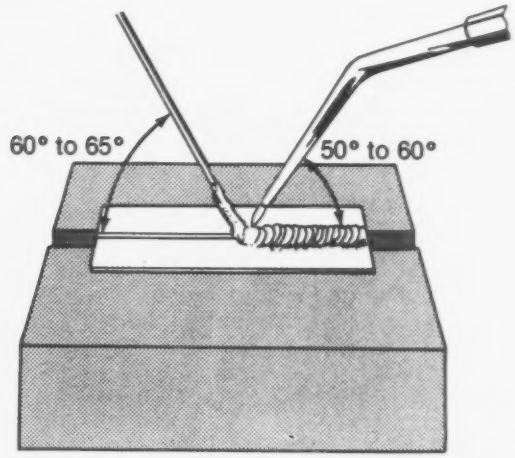
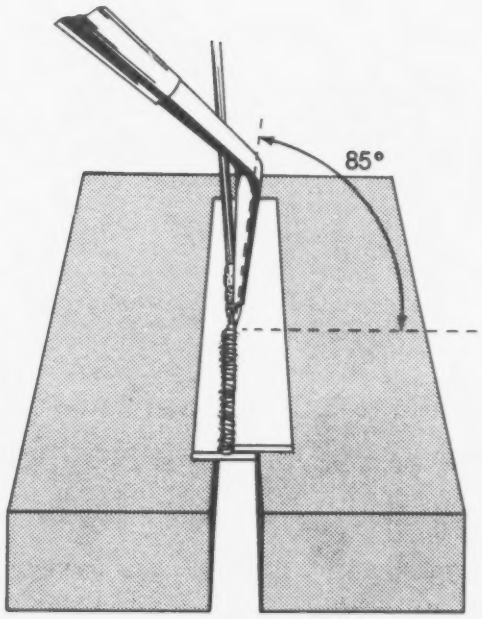


FIGURE 7



JOB SHEET #2

K. Melt a small amount of bronze rod onto surface; allow it to spread along entire width of seam when a cherry red color occurs

L. Start depositing proper size bead when base meal is tinned sufficiently

(NOTE: When metal is not hot enough, the bronze will form into drops; when metal is too hot, bronze tends to boil.)

M. Complete weld and show to instructor for evaluation

N. Clean work area; clean and put away all tools and equipment

OXYACETYLENE BRAZE WELDING
UNIT III

JOB SHEET #3 — BRAZE WELD A TEE OR FILLET JOINT

I. Equipment and materials

- A. Oxyacetylene welding unit
- B. Gloves
- C. Safety glasses
- D. Welding goggles
- E. Manufacturer's recommended welding tip, or #5
- F. Wire brush
- G. Flint lighter
- H. 2 firebricks
- I. 2 strips mild steel 1 1/4" × 8" × 1/8"
- J. Manufacturer's recommended bronze filler rod
- K. Welding flux
- L. Service manual for oxyacetylene welding unit

II. Procedure

(NOTE: Be sure to follow shop safety regulations at all times.)

- A. Clean metal
- B. Place metal on firebricks
- C. Turn on oxyacetylene unit
- D. Adjust working pressure of oxygen and acetylene to 5 pounds

  (NOTE: Follow manufacturer's recommendations.)
- E. Light torch and adjust to a neutral or slightly oxidizing flame
- F. Preheat end of brazing rod and dip into flux, or used fluxed rod
- G. Place one mild steel strip on base strip to form a 90-degree angle; support vertical strip until tacked
- H. Tack metal in place using bronze filler rod
- I. Preheat joint at right end; weld to left

JOB SHEET #3

J. Hold torch and filler rod as shown in Figures 8 and 9

FIGURE 8

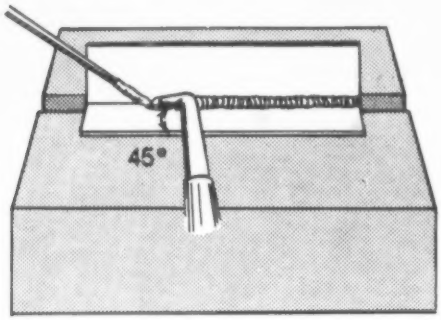
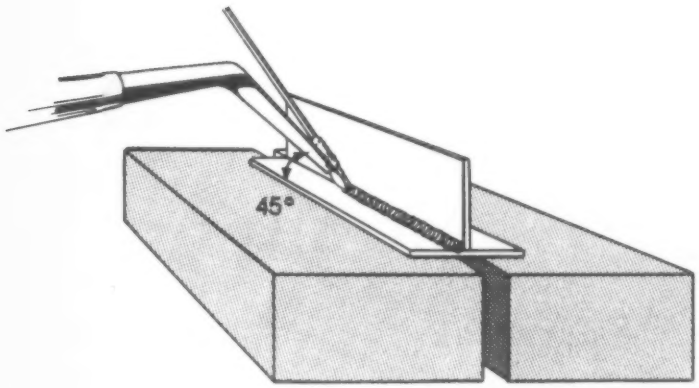


FIGURE 9



JOB SHEET #3

K. Melt a small amount of bronze rod onto surface; allow it to spread along entire width of seam when a cherry red color occurs

L. Start depositing proper size bead when base metal is tinned sufficiently

(NOTE: When metal is not hot enough, the bronze will form into drops; when metal is too hot, bronze tends to boil.)

M. Complete weld and show to instructor for evaluation

N. Clean work area; clean and put away all tools and equipment

OXYACETYLENE BRAZE WELDING
UNIT III

TEST

NAME _____ SCORE _____

1. Match to their correct definitions terms associated with oxyacetylene braze welding. Write the correct numbers in the blanks. Definitions are continued on the next page.

_____a.	Rod that has a mixture of metallic properties; composed of two or more elements of which one is a metal	1. Braze welding
_____b.	Metal to be welded	2. Fusion welding
_____c.	Heating base metal to a dull red color and depositing a bead over the seam (joint) with a filler rod, without melting the base metal	3. Ductile
_____d.	Weld between two metal joints on the same plane	4. Alloy rod
_____e.	Capable of being drawn or stretched	5. Fusion
_____f.	Bronze rod with characteristics similar to base metal	6. Oxidizing
_____g.	Chemical used to clean metals and to promote fusion and adhesion during welding process	7. Base metal
_____h.	Process of liquefying by melting	8. Filler rod
_____i.	Joining pieces of metal by heating adjoining edges to the fusion point and allowing them to flow or run together and then cool	9. Molten
_____j.	Property of metals that allows them to be bent or permanently distorted without rupture	10. Tinning operation
_____k.	Liquefied by heat	11. Oxide
_____l.	Substance produced when oxygen is combined with an element	12. Malleability
_____m.	Combining oxygen with another substance	13. Flux
		14. Butt joint
		15. Penetration
		16. Tack weld

TEST

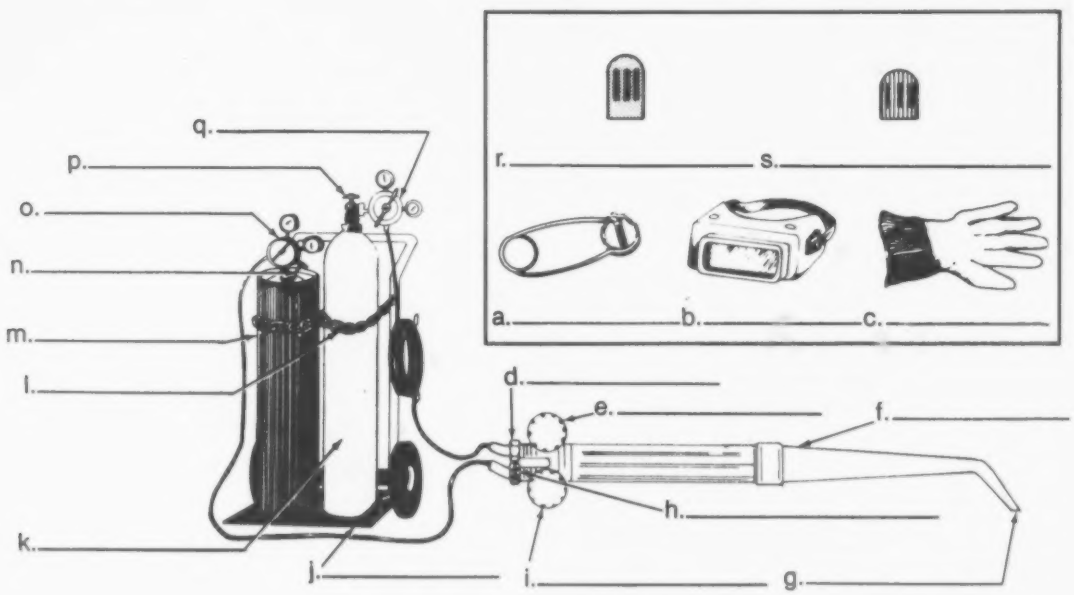
_____n. Process of melting a small amount of bronze rod onto surface of base metal and allowing it to spread along entire seam (joint)

_____o. Short weld used for temporarily holding material in place

_____p. Distance from original surface of base metal to that point at which fusion ceases

2. Identify the oxyacetylene welding equipment illustrated below. Write the correct names

Acetylene cylinder
Acetylene fitting (hex-grooved nut, left-hand threads)
Acetylene regulator
Oxygen cylinder
Safety chain
Flint lighter
Acetylene cylinder valve
Oxygen cylinder valve
Oxygen cylinder cap
Torch body
Oxygen torch valve
Acetylene torch valve
Welding gloves
Oxygen fitting (right-hand threads)
Oxygen regulator
Welding tip
Cylinder truck
Welding goggles
Acetylene cylinder cap



TEST

3. Name factors that determine selection of welding tip size.

   a. _____

   b. _____

4. Distinguish between braze welding and fusion welding. Write a "B" in the blanks before braze welding and an "F" in the blanks before fusion welding.

   _____a. Rod with characteristics similar to base metal is melted to join with melted base metal

   _____b. Bronze rod is used to lay a thin coat of bronze along seam

   _____c. Base metal is not melted

   _____d. Base metal is melted and joined

5. Distinguish between advantages and disadvantages of braze welding. Write an "A" in the blanks before advantages, and a "D" in the blanks before disadvantages.

   _____a. May be used to join different kinds of metals

   _____b. Uses less gas

   _____c. Bronze rod is expensive to use

   _____d. Can be used to weld malleable castings

   _____e. Increases speed of joining metals

   _____f. Cannot be used on metal where stress is a factor

   _____g. Will not bond unless base metal has corrosion-resistant properties similar to bronze

   _____h. Because it is not heated to a molten condition, provides less chance of destroying main characteristics of base metal

   _____i. Is not recommended for parts that are raised to temperatures higher than melting point of bronze, either in service or during heat treatment

   _____j. Can be used to weld thin metals

   _____k. Bronze loses its strength at temperatures above 500°F

TEST

6. State the importance of having a chemically clean metal surface in braze welding.

   a. _____

   b. _____

   c. _____

7. State methods of removing oxides from a clean metal surface.

   a. _____

   b. _____

8. Distinguish among characteristics of oxyacetylene welding flames. Write a "C" in the blanks before characteristics of a carburizing flame, an "N" before neutral flame, and an "O" before oxidizing flame.

   _____a. Reaches temperature of 5,950°F

   _____b. Burns excess of oxygen

   _____c. Burns excess of acetylene

   _____d. Is recommended for cutting cast iron

   _____e. Is hottest flame

   _____f. Is identified by clear, well-defined white cone

   _____g. Oxidizes the metal, causing it to harden and become brittle

   _____h. Is recommended for brazing

   _____i. Burns equal amounts of oxygen and acetylene

   _____j. Introduces carbon into weld, causing hardening of metal, which weakens weld

   _____k. Is identified by short, white inner cone

9. Select from the following list purposes of flux. Write an "X" in the blank before each correct answer.

   _____a. Preventing oxidation of filler metal

   _____b. Preventing base metal from melting

   _____c. Floating and removing oxides already present

_____d. Decreasing flow of filler metal

_____e. Bringing filler metal into immediate contact with metals being joined

_____f. Cleaning base metal

_____g. Keeping filler metal from adhering to base metal

_____h. Preventing filler metal from penetrating pores of base metal

10. Describe reactions of molten bronze at different base metal temperatures.

a. Too hot — _____

_____

b. Too cold — _____

_____

c. Correct — _____

_____

(NOTE: Test question 11 lists the job sheets. They are an important part of this test. If they have not been completed, check with your instructor.)

11. Demonstrate the ability to

a. Braze weld a square-groove butt joint.

b. Braze weld a lap joint.

c. Braze weld a tee or fillet joint.

OXYACETYLENE BRAZE WELDING
UNIT III

ANSWERS TO TEST

1.	a.	4	g.	13	m.	6
	b.	7	h.	5	n.	10
	c.	1	i.	2	o.	16
	d.	14	j.	12	p.	15
	e.	3	k.	9		
	f.	8	l.	11		

2.	a.	Flint lighter	k.	Oxygen cylinder
	b.	Welding goggles	l.	Safety chain
	c.	Welding gloves	m.	Acetylene cylinder
	d.	Oxygen fitting (right-hand threads)	n.	Acetylene cylinder valve
	e.	Oxygen torch valve	o.	Acetylene regulator
	f.	Torch body	p.	Oxygen cylinder valve
	g.	Welding tip	q.	Oxygen regulator
	h.	Acetylene fitting (hex-grooved nut, left-hand threads)	r.	Oxygen cylinder cap
			s.	Acetylene cylinder cap
	i.	Acetylene torch valve		
	j.	Cylinder truck		

3. a. Thickness of base metal
   b. Size of welding rod

4. a. F
   b. B
   c. B
   d. F

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ANSWERS TO TEST

5.

a.	A	e.	A	i.	D
b.	A	f.	D	j.	A
c.	D	g.	D	k.	D
d.	A	h.	A		

6. a. Ensures that the molten bronze will adhere to base metal
   b. Allows weld to form stronger bond on base metal
   c. Allows bronze to flow smoothly and evenly over entire weld area

7. a. Mechanical means
   b. Chemical flux

8.

a.	N	e.	O	i.	N
b.	O	f.	N	j.	C
c.	C	g.	O	k.	O
d.	C	h.	O		

9. a, c, e, f

10. Description should include the following
    a. Too hot — Tends to boil and form little balls
    b. Too cold — Forms into drops rather than flowing evenly over surface
    c. Correct — Spreads evenly and flows over a considerable area

11. Performance skills evaluated to the satisfaction of the instructor